US-APWR

Introductory Remarks

Overview of US-APWR Seismic Technical Reports

November 7, 2011

Mitsubishi Heavy Industries, Ltd

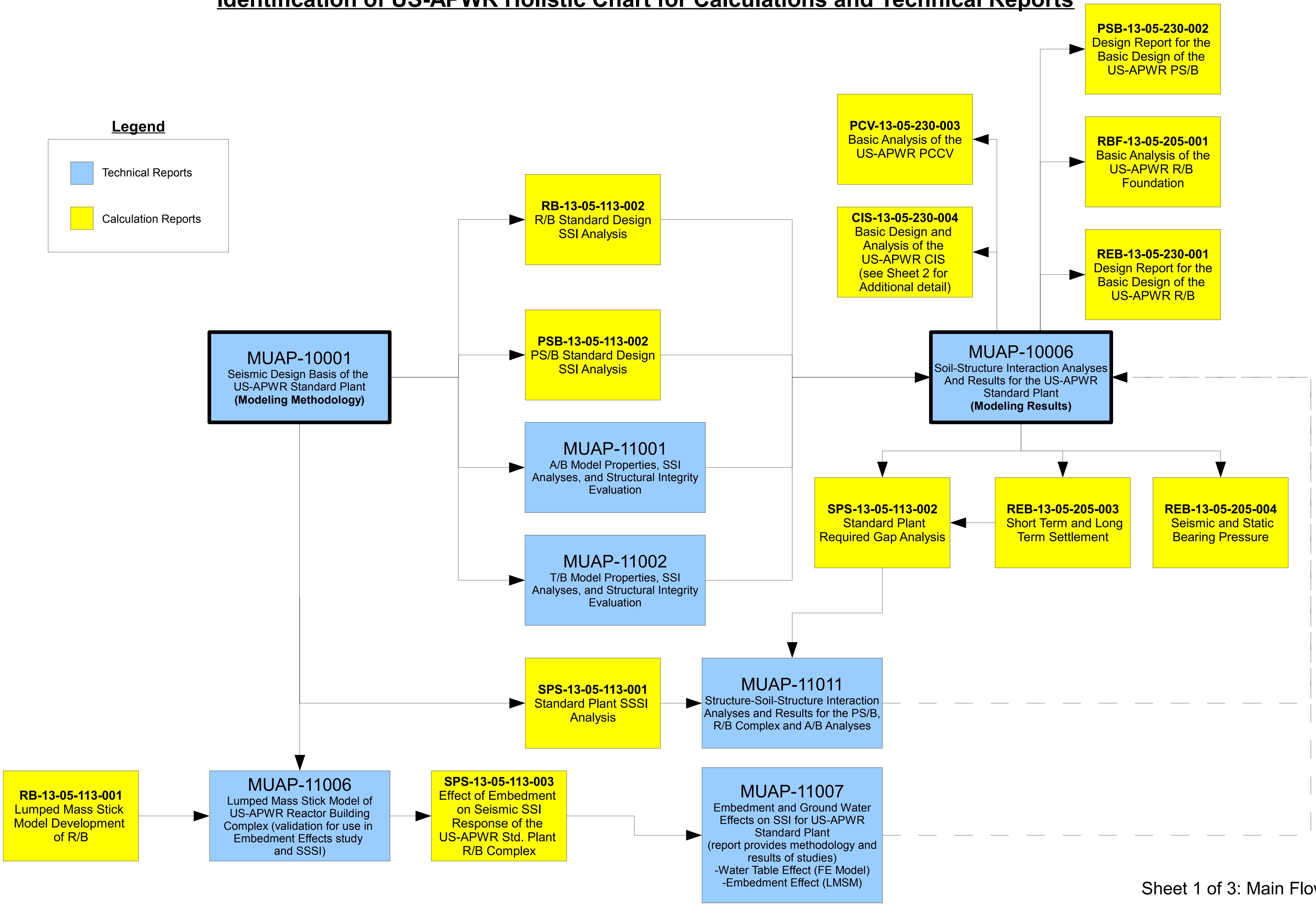
Introductory Remarks

- Purpose of presentation
  - ✓ Provide a review of the revision contents of Seismic Technical Reports submitted in October 2011 and Future Plans
  - ✓ Address the NRC Staff questions on changes to the design basis input (Captured in Presentations B and G)

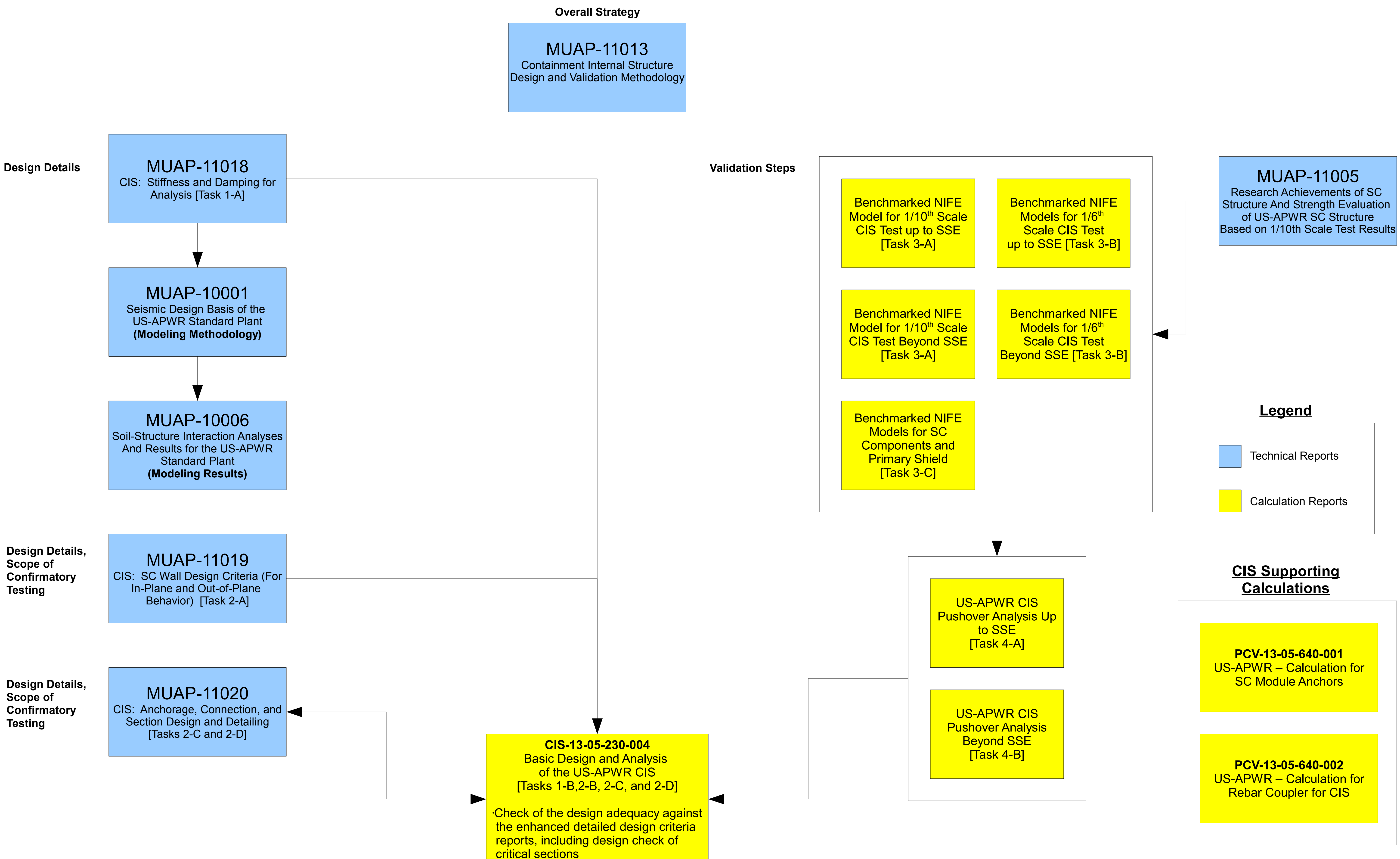
Introductory Remarks

- ➢ Presentation topics to be covered today include:
  - ✓ A – Introductory Remarks
    - ✓ Provide Staff with Holistic Flow Chart of Calculations and Technical Reports
  - ✓ B – Seismic Design Basis Methodology and Results MUAP-10001 and MUAP-10006
  - ✓ C – Study Evaluations MUAP-11007
  - ✓ D – Turbine Building MUAP-11002
  - ✓ E – Current Status of MUAP-11001 and MUAP-11011
  - ✓ F – RAI Disposition Plan for Technical Reports
  - ✓ G – Discussion of Time Histories, Seismic Demands, and Process for Selection
  - ✓ H – Concluding Remarks

Identification of US-APWR Holistic Chart for Calculations and Technical Reports



Sheet 1 of 3: Main Flow of Reports



Sheet 2 of 3: Additional CIS Details

Main Calculation

PCV-13-05-230-003 Calculation Report Design Report for the Basic Design of the US-APWR PCCV

Supporting Calculations

- **PCV-13-05-230-004** Basic Design Verification of the US-APWR PCCV
- **PCV-13-05-230-005** PCCV Thermal Analysis
- **PCV-13-05-230-006** PCCV Creep Evaluation
- **PCV-13-05-230-007** PCCV Tendon Prestress Evaluation
- **PCV-13-05-230-008** Basic Design of PCCV Liner System
- **PCV-13-05-230-009** PCCV Postprocessor Theory
- **PCV-13-05-230-010** PCCV Buttress Design
- **PCV-13-05-230-011** PCCV Equipment Hatch and Airlock Analysis
- **PCV-13-05-230-012** PCCV Equipment Hatch and Airlock Design
- **PCV-13-05-230-013** Submodeling for Strain Near PCCV Penetrations
- **PCV-13-05-271-001** US-APWR – Concrete Calculation for Evaluation of Local Stresses and Rebar Requirements at Sleeve Penetrations
- **PCV-13-05-272-001** Design of PCCV Mechanical Penetrations
- **PCV-13-05-272-002** Design of PCCV Electrical and Ventilation Penetrations
- **PCV-13-05-272-003** Design of PCCV Fuel Transfer Tube Penetration
- **PCV-13-05-272-004** PCCV Penetration Design Basis Calculation
- **PCV-13-05-277-001** US-APWR – Preliminary Calculation for Polar Crane Runway Girder
- **PCV-13-05-277-002** US-APWR – Preliminary Design of PCCV Polar Crane Structural Steel and Anchorage to Concrete
- **PCV-13-05-262-01** US-APWR – Calculation for Attachment Loading to the Liner Plate
- **PCV-13-05-262-02** Calculation for 4 Typical Attachments to Containment Wall Liner Plate
- **PCV-13-05-640-001** US-APWR – Calculation for SC Module Anchors
- **PCV-13-05-640-002** US-APWR – Calculation for Rebar Coupler for CIS

Main Calculation

PSB-13-05-230-002 Design Report for the Basic Design of the US-APWR PS/B

Supporting Calculations

- **PSB-13-05-113-001** Dynamic Model Development And Validation of PS/B
- **PSB-13-05-113-002** PS/B Standard Design SSI Analysis
- **PSB-13-05-205-001** Stability Evaluation of PS/B

Main Calculation

REB-13-05-230-001 Design Report for the Basic Design of the US-APWR R/B

Supporting Calculations

- **RB-13-05-113-002** R/B Standard Design SSI Analysis
- **RB-13-05-113-003** Dynamic FE Model Development of R/B
- **RBF-13-05-205-001** Basic Analysis of the US-APWR R/B Foundation (including stability evaluation)
- **RBF-13-05-205-002** Basic Analysis of R/B Foundation (ASME)

Main Calculation

SPS-13-05-113-003 Effect of Embedment on Seismic SSI Response of the US-APWR Std. Plant R/B Complex

Shared Supporting Calculation

- **RB-13-05-113-001** Lumped Mass Stick Model Development of R/B

Main Calculation

SPS-13-05-113-001 Standard Plant SSSI Analysis

Shared Supporting Calculation

- **RB-13-05-113-001** Lumped Mass Stick Model Development of R/B

Sheet 3 of 3: Additional Calc Report Details

US-APWR

MUAP-10001 & MUAP-10006

Overview of Seismic Design Basis Methodology and Results

November 7, 2011

Mitsubishi Heavy Industries, Ltd

Purpose and Contents

- The purpose of this presentation is to:
  - ✓ Provide an overview of the revisions made in the recently submitted Technical Reports (TR) documenting the basis for standard seismic design of US APWR Category I buildings
  - ✓ Further explain the reason for the modification of generic site profiles for site-independent SSI analyses
  - ✓ Describe the impact of the recent revisions on the standard design basis ISRS, SSE loads and maximum seismic displacements

- Contents of the presentation:

  1. Revised Design Basis Documents
  2. MUAP-10001 Revisions 3 and 4
  3. MUAP-10006 Revision 2
  4. Summary

1. Revised Design Basis Documents

➤ Revised Seismic Basis for Standard Design of US-APWR Plant is documented in:

✓ **TR MUAP-10001 Revisions 3 and 4**:
Seismic Design Bases of the US-APWR Standard Plant

✓ **TR MUAP-10006 Revision 2**:
Soil-Structure Interaction Analyses and Results for the US-APWR Standard Plant

2. MUAP-10001 Revisions 3 and 4

- **Updated Content of TR MUAP-10001:**

1. Design Ground Motion Time Histories (Updated in Revision 4)
2. Generic Layered Site Profiles (Updated in Revision 4)
3. Structural FE Model for Seismic Response Analysis of R/B Complex (Updated in Revision 3)
4. Structural FE Model for seismic response analysis of PS/B (Updated in Revision 3)
5. Consideration of Concrete Cracking in Seismic Response Analysis (Updated in Revision 3)

2. MUAP-10001 Revisions 3 and 4

1. Updates to Design Ground Motion Time Histories in Section 4.1 and 5.1 of TR MUAP-10001 Revision 4:

   ✓ Artificial time histories in previous revisions of TR MUAP-10001 are revised following the same methodology compliant to SRP 3.7.1, Subsection II..1.B, Option 1, Approach 2

   ✓ The seed time histories changed from Northridge Mt Baldy, CA records (1994) to Nahanni, Canada Earthquake Site 3 records (1985)

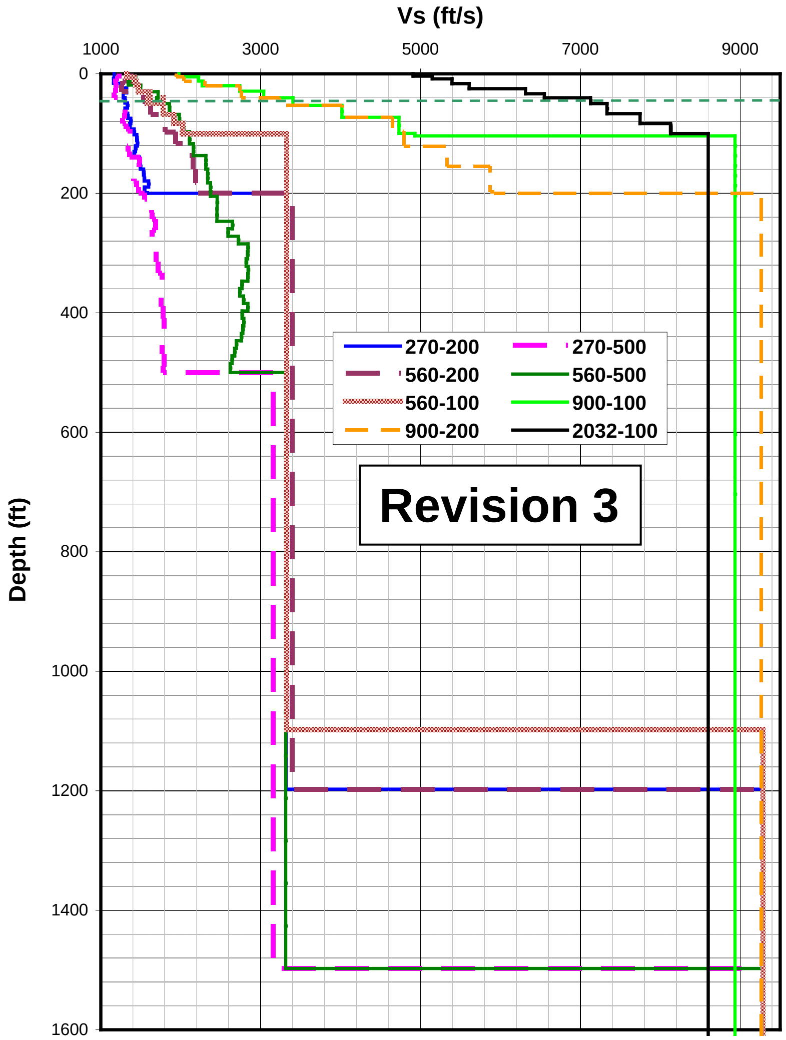
   - 5% damping ARS of the revised time histories provide better match to US-APWR CSDRS

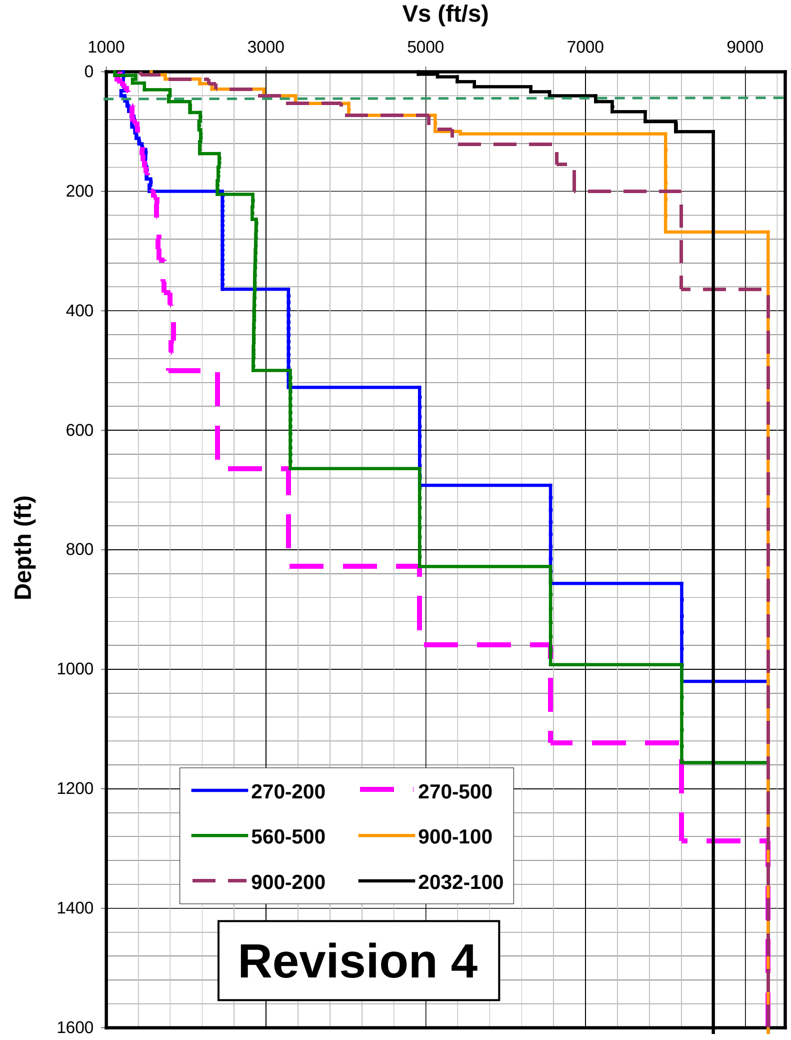
2. MUAP-10001 Revisions 3 and 4

2. Updates to Generic Layered Site Profiles in Section 4.2 and 5.2 of TR MUAP-10001 Revision 4:
   - Site Profiles 560-100 and 560-200 are removed from the standard seismic design database
   - EPRI soil degradation curves are used instead of unpublished rock degradation curves
   - Hard rock base is replaced with sedimentary rock type of profile with gradual increase of stiffness
   - Profiles with nominal S-wave velocity of 900 m/sec are modified by introducing steeper increase of rock stiffness with depth
   - Clarifications and explanations are provided of how the developed generic profile data is used as input for site-independent SSI analyses and to address RAI (850-6002) questions

2. MUAP-10001 Revisions 3 and 4

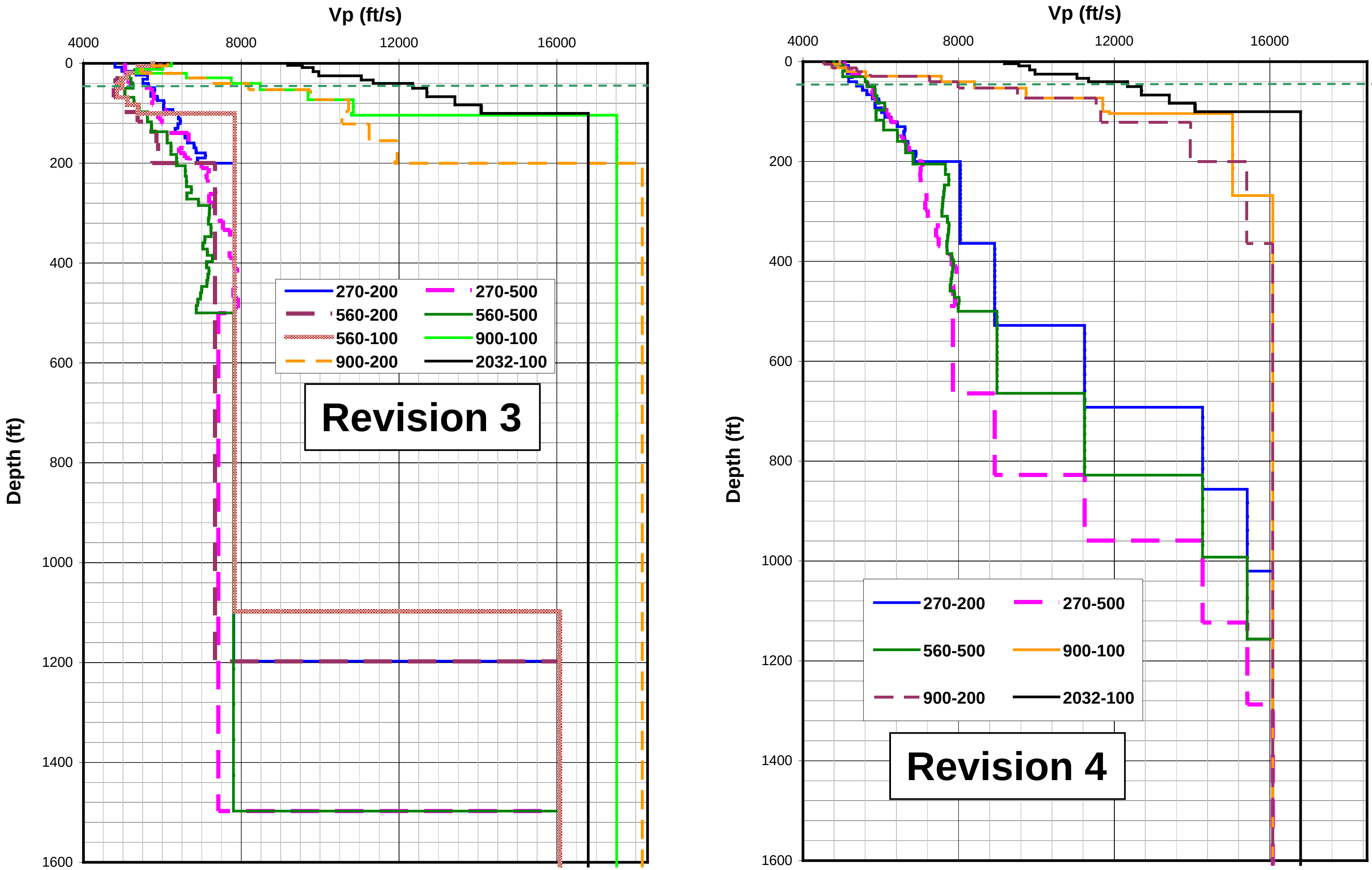
➢ Strain Compatible S - Wave Velocity Profiles





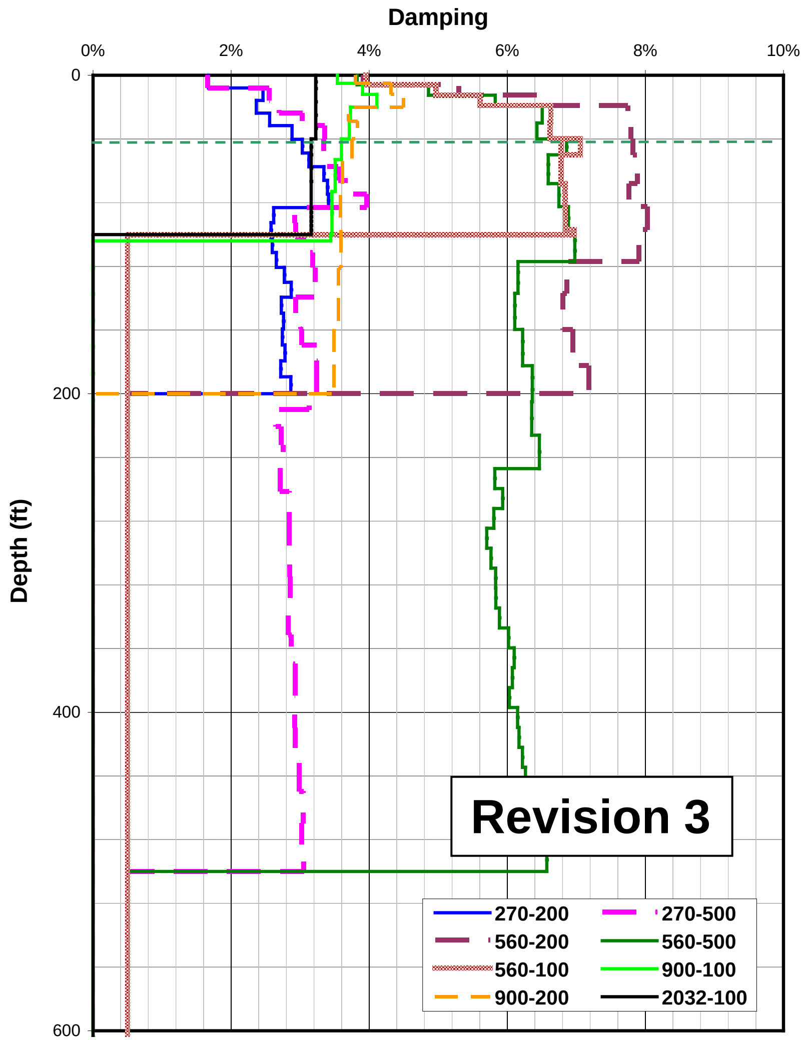
2. MUAP-10001 Revisions 3 and 4

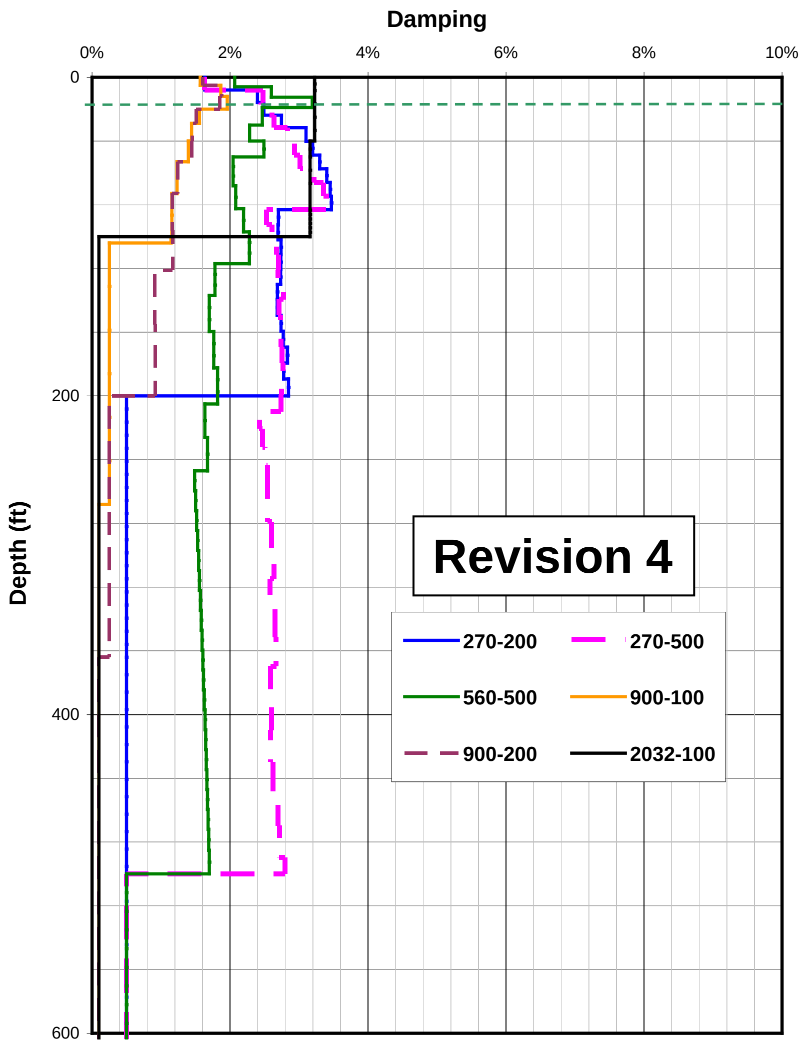
➢ Strain Compatible P - Wave Velocity Profiles



2. MUAP-10001 Revisions 3 and 4

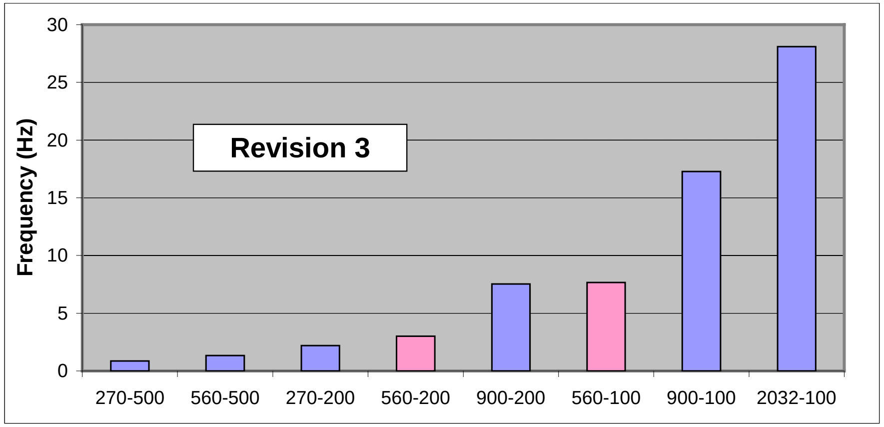
➢ Strain Compatible Damping Profiles

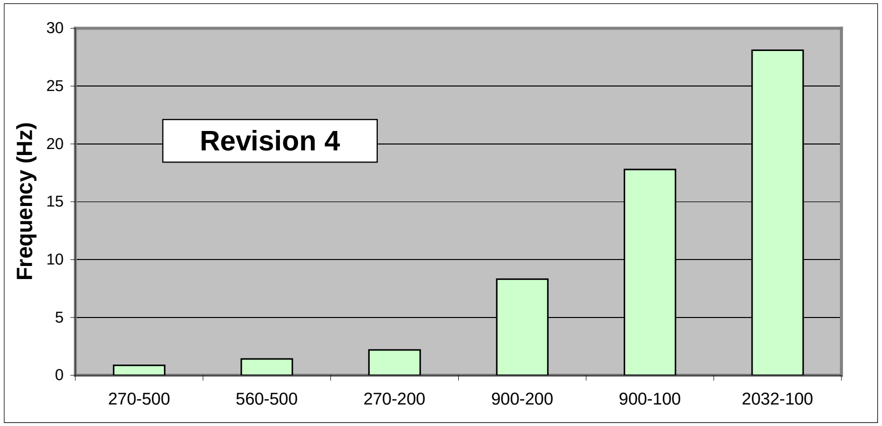




2. MUAP-10001 Revisions 3 and 4

- **Shear Column Frequencies presented in Section 5.2 of MUAP 10001 Revision 2:**
  - ✓ **Removal of 560-100 and 560-200 has negligible effect on the shear column frequency distribution**





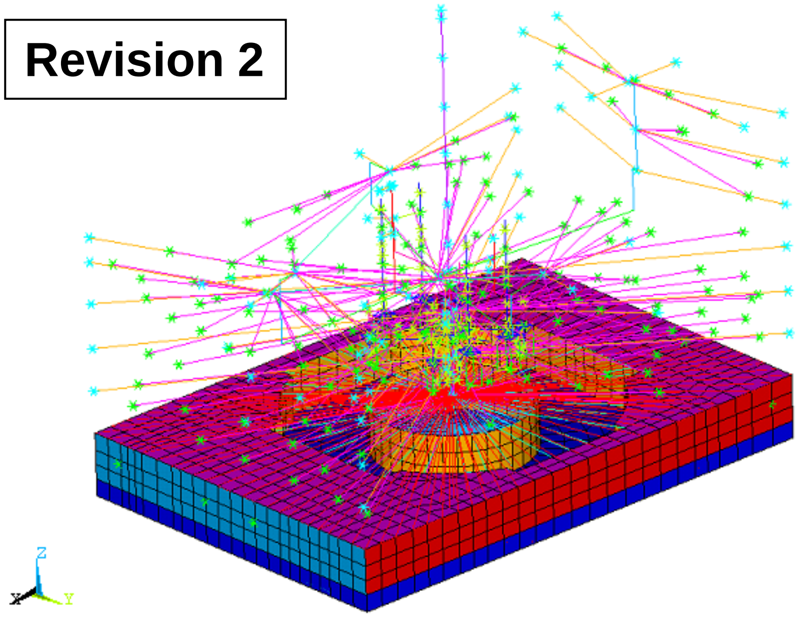
2. MUAP-10001 Revisions 3 and 4

3. Updates to R/B Complex Structural Model in Section 4.3 (Methodology) and Section 5.3 (Validation Results) of TR MUAP-10001 Revision 3:
   - ✓ Dynamic FE model of R/B Complex developed to address modeling deficiencies of R/B Complex lumped mass stick model
   - ✓ Static and Dynamic validation analyses performed on Dynamic FE model and Detailed FE model to ensure compliance with modeling requirements of SRP 3.7.2
   - ✓ Seismic basis for standard design of R/B Complex developed solely from responses obtained from site-independent SSI analyses of dynamic FE model

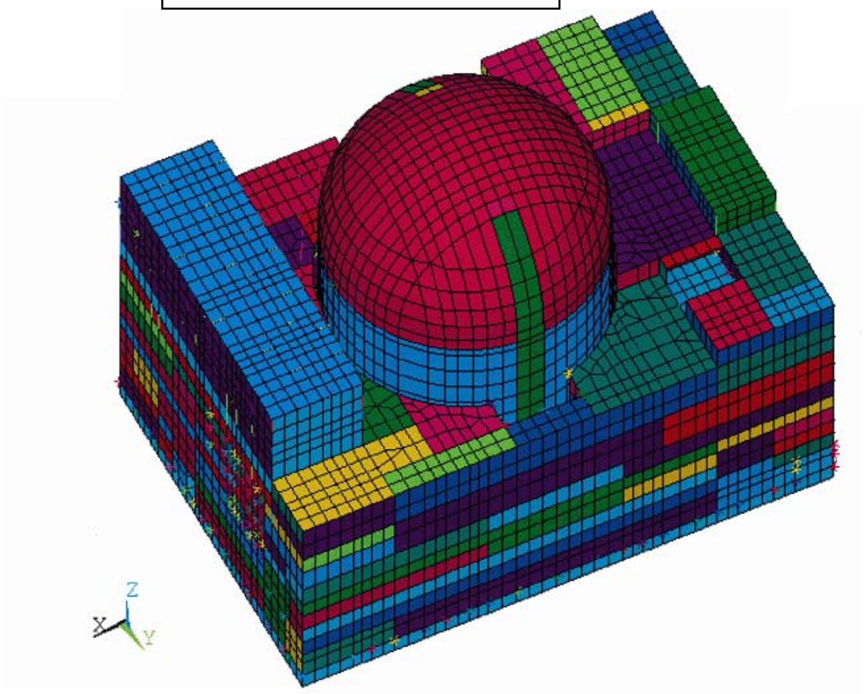
2. MUAP-10001 Revisions 3 and 4

➢ **Structural Model for SSI analyses of R/B Complex**

Revision 2



Revisions 3 & 4

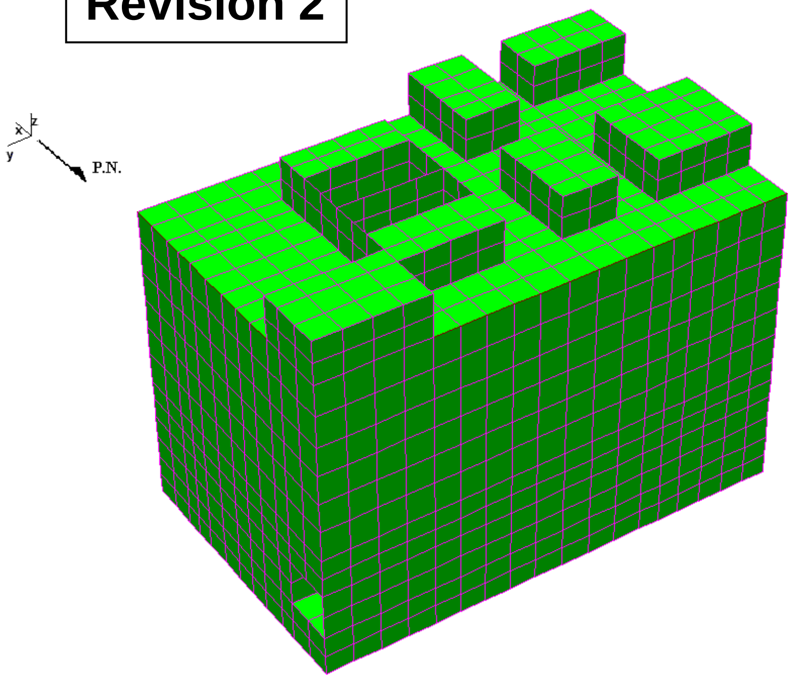


2. MUAP-10001 Revisions 3 and 4

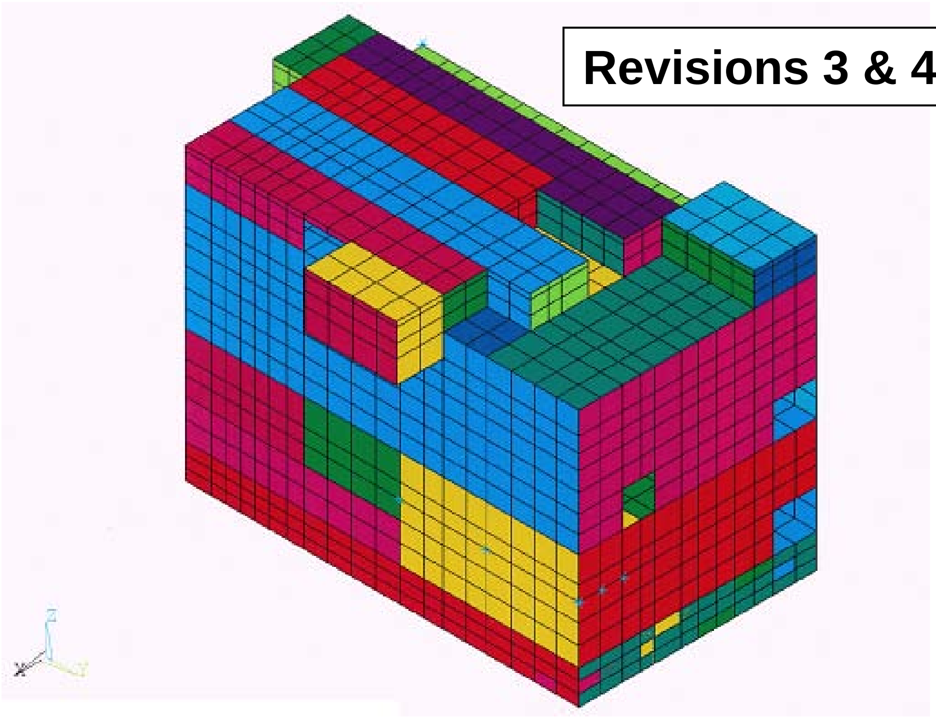
4. Updates to PS/B Structural Model in Section 5.4 of TR MUAP-10001 Revision 3
   - Minor changes of geometry of PS/B Dynamic FE model introduced to incorporate design changes in PS/B roof configuration
   - Model with refined FE mesh used for analyses of all generic site conditions
   - Validation analyses re-performed on revised Dynamic FE model and Detailed FE model to ensure compliance with modeling requirements of SRP 3.7.2
   - Seismic basis for standard design of PS/B developed solely from responses obtained from site-independent SSI analyses of dynamic FE model

➢ Structural Model for SSI analyses of PS/B

Revision 2



Revisions 3 & 4



2. MUAP-10001 Revisions 3 and 4

5. Updates to Methodology for Consideration of Concrete Cracking in Section 4.5 of TR MUAP-10001 Revision 3

- ✓ To address variations in seismic response due to effects of concrete cracking, FE models with two bounding stiffness and damping levels are considered:
  - i. Full (Uncracked concrete) stiffness and lower level OBE damping
  - ii. Reduced (Cracked concrete) stiffness and higher level SSE damping
- ✓ MUAP-11018 replaces Appendix A of MUAP-10001 (R3) as source for the bounding stiffness and damping properties of CIS dynamic FE model for normal operating and accidental condition stress levels
- ✓ Appendix B of MUAP-10001 presents the bounding stiffness and damping properties of PCCV dynamic FE model for normal operating and accidental condition stress levels
- ✓ Bounding stiffness and damping properties of R/B and PS/B models are based on the recommendation of ASCE 43-05

2. MUAP-10001 Revisions 3 and 4

- **Methodology for Consideration of Concrete Cracking in Section 4.5 of TR MUAP-10001 Revision 3**
  - ✓ ISRS for design of Category I and II SSC's developed using envelope of SSI responses obtained from models with the two levels of stiffness
  - ✓ SSE loads for Containment Structures (PCCV and CIS) based on envelope of SSI responses obtained from two levels of stiffness in order to address variations of cracking patterns under normal operating and accidental thermal conditions
  - ✓ Stability evaluations and design of reinforced concrete structures (R/B and PS/B) based on consideration of ultimate state of stress corresponding to cracked concrete properties
  - ✓ No methodology change in Revision 4

2. MUAP-10001 Revisions 3 and 4

➢ **Consideration of concrete cracking effects in the development of standard design basis**

Structure	Stiffness	Damping	ISRS	SSE Loads	Stability
CIS	Full (uncracked)	4%	X	X	
	Reduced (cracked)	5%	X	X	X
PCCV	Full (uncracked)	3%	X	X	
	Reduced (cracked)	5%	X	X	X
R/B	Full (uncracked)	4%	X		
	Reduced (cracked)	7%	X	X	X
PS/B	Full (uncracked)	4%	X		
	Reduced (cracked)	7%	X	X	X

3. MUAP-10006 Revision 2

- **Updated Content of TR MUAP-10006**:
  1. SSI Analysis Methodology
  2. US-APWR Seismic Design Bases
  3. SSI Responses from updated set of site-independent SSI analyses
  4. In-Structure Response Spectra (ISRS)
  5. Reason and Impact of the Revision of Generic Site Profiles Database
  6. Maximum Seismic Displacements
  7. SSE Loads
  8. Stability Evaluations and Calculations of Dynamic Bearing Pressure

1. Updates to SSI Analysis Methodology in TR MUAP-10006 Revision 2, Section 3.1:

- ✓ Site-independent SSI analyses use higher cut-off frequencies to better capture energy of input motion at higher frequencies
- ✓ The lower boundary of the layered subgrade model is established at depth of approximately 900 ft; The site model is extended below the layered subgrade by an elastic half-space modeled by 10 additional layers
- ✓ R/B Complex seismic responses obtained from surface mounted models (shear keys are not included in the models) with two bounding levels of stiffness and damping properties
- ✓ PS/B seismic responses obtained from models with two bounding levels of stiffness and damping properties that include 40 ft deep ballast embedded in the subgrade

- **Passing wave frequencies of SSI models and cut-off frequencies of SSI analyses ensure that standard design basis ISRS envelope responses up to 50 Hz**

Site Profiles	Vs (top subgrade layer) ft/s	R/B Complex			PS/B		
		d_{FE} ft	$f_{FE\ max}$ Hz	f_{cutoff} Hz	d_{FE} ft	$f_{FE\ max}$ Hz	f_{cutoff} Hz
270-500	1308	9	29.1	40	6	43.9	50
270-200	1232		27.4	40		41.3	50
560-500	1779		39.5	50		59.3	50
900-200	3197		71.0	70		106.6	70
900-100	3368		74.8	70		112.3	70
2032-100	7126		158.4	70		237.5	70

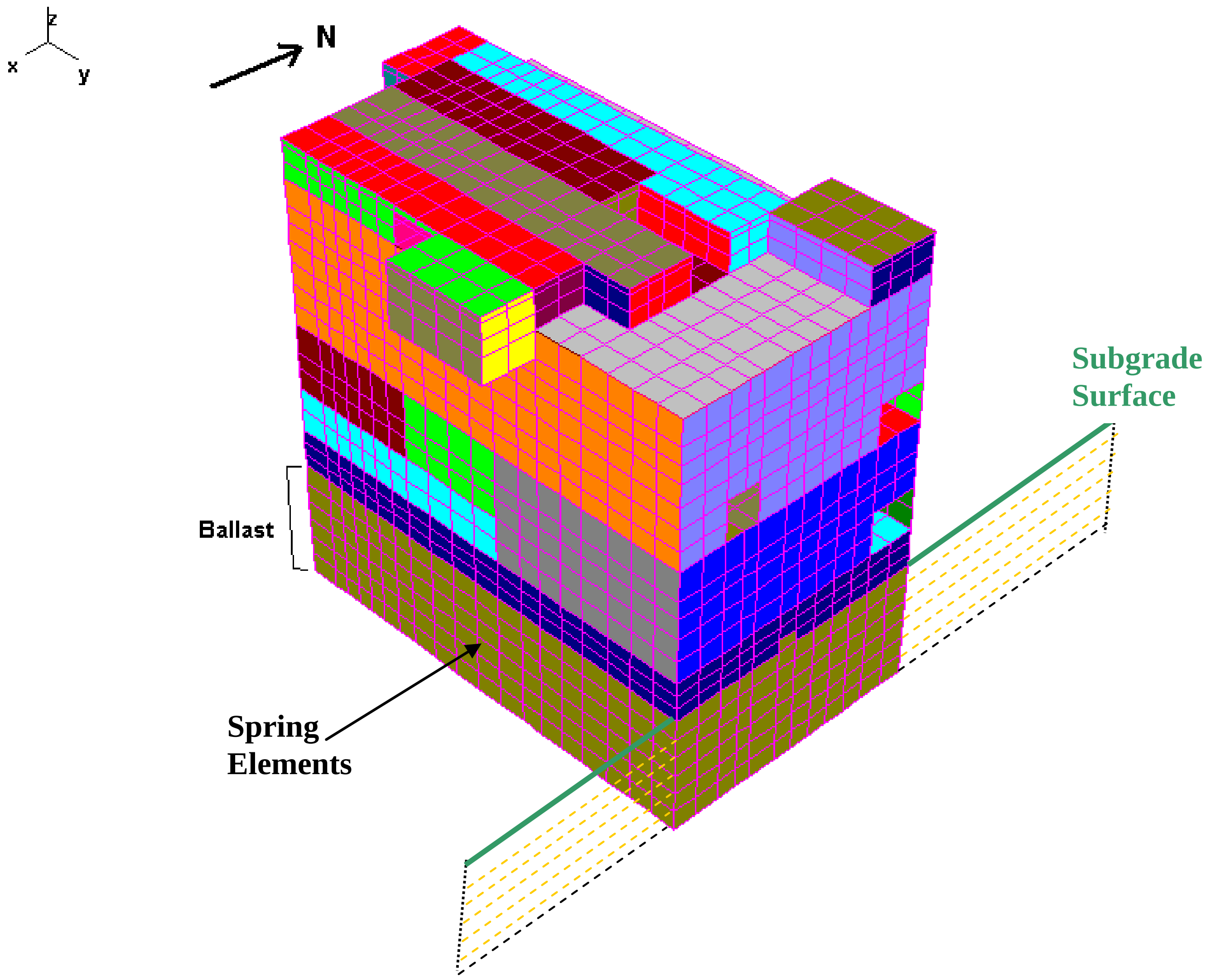
d_{FE} – Nominal FE mesh size

f_{FE_max} – Maximum passing frequency

f_{cutoff} – Cut-off frequency of analysis

US-APWR

➢ PS/B Structural Model with Ballast



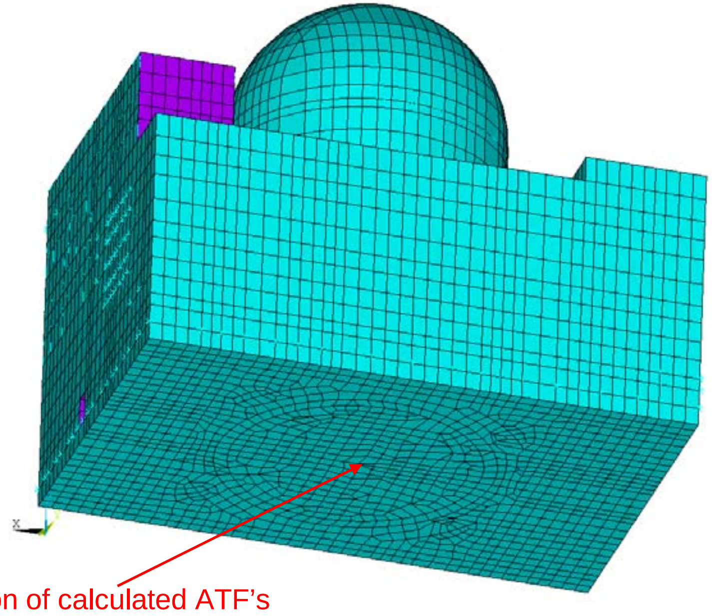
3. MUAP-10006 Revision 2

2. Updates to Seismic Design Bases in TR MUAP-10006 Revision 2 , Section 3.2:

- ✓ Information regarding input generic subgrade profiles updated to reflect revisions made in MUAP-10001 Revision 4
- ✓ Layering of generic subgrade profiles used for site independent SSI analyses of PS/B adjusted to match the FE mesh of concrete ballast
- ✓ Information regarding input acceleration time histories of seismic ground motion updated to reflect revisions made in MUAP-10001 Revision 4
- ✓ Information regarding R/B Complex and PS/B structural models updated to reflect revisions made in MUAP-10001 Revision 4 and to describe the PS/B ballast

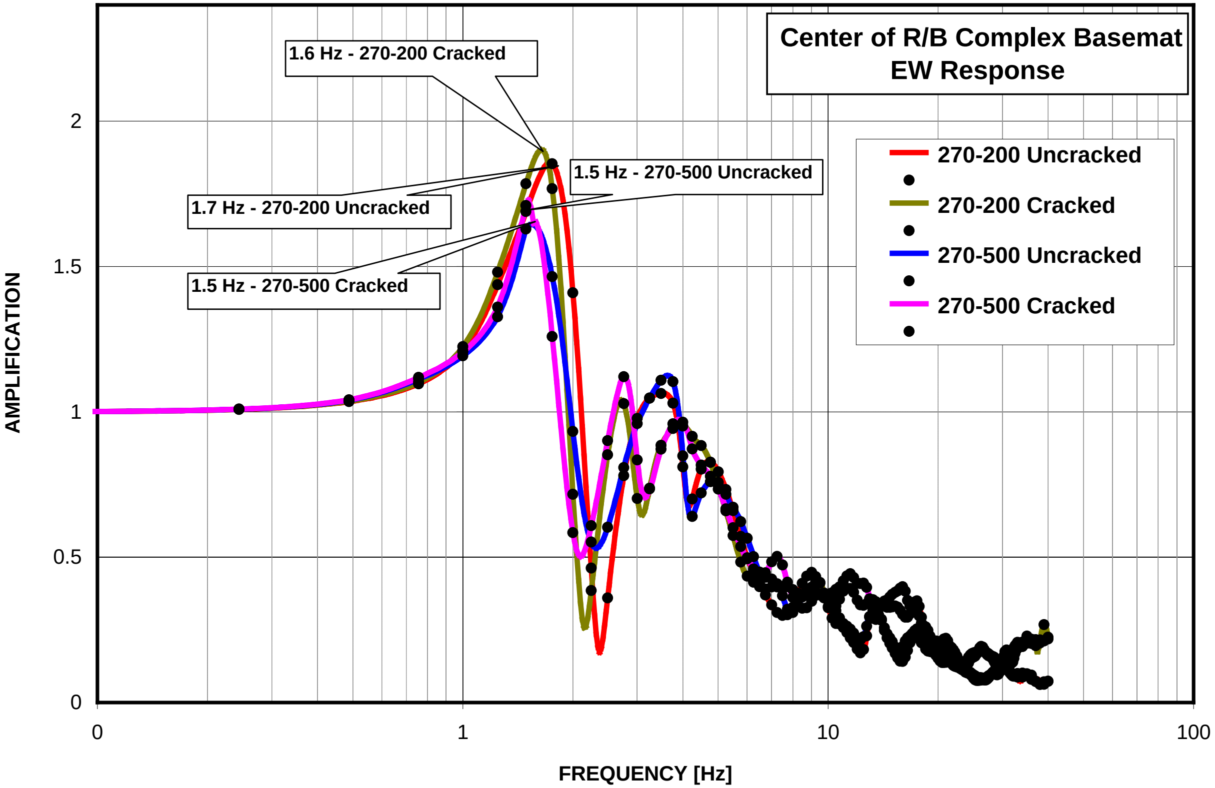
3. SSI Responses from updated set of R/B Complex SSI analyses in TR MUAP-10006 Revision 2, Section 4.1:

- ✓ Site-independent SSI analyses capture a wide range of SSI responses to ensure applicability of standard design for majority of candidate sites within Continental US
- ✓ Acceleration transfer functions (ATFs) for response at center of basemat bottom serve as indicator of range of SSI responses captured by standard design



3. SSI Responses from updated set of R/B Complex SSI analyses in TR MUAP-10006 Revision 2, Section 4.1:

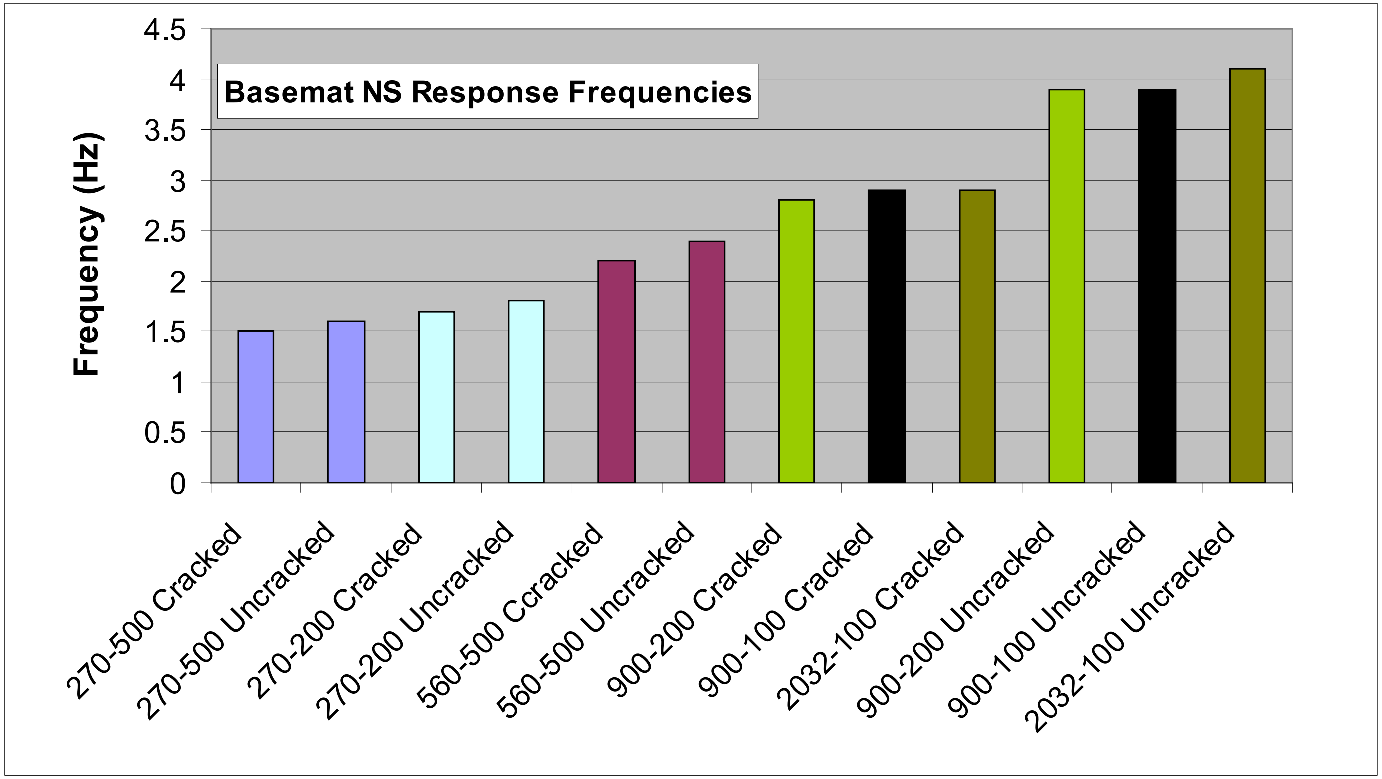
- ✓ Frequencies where first peaks of the transfer functions occur are summarized for comparison



3. MUAP-10006 Revision 2

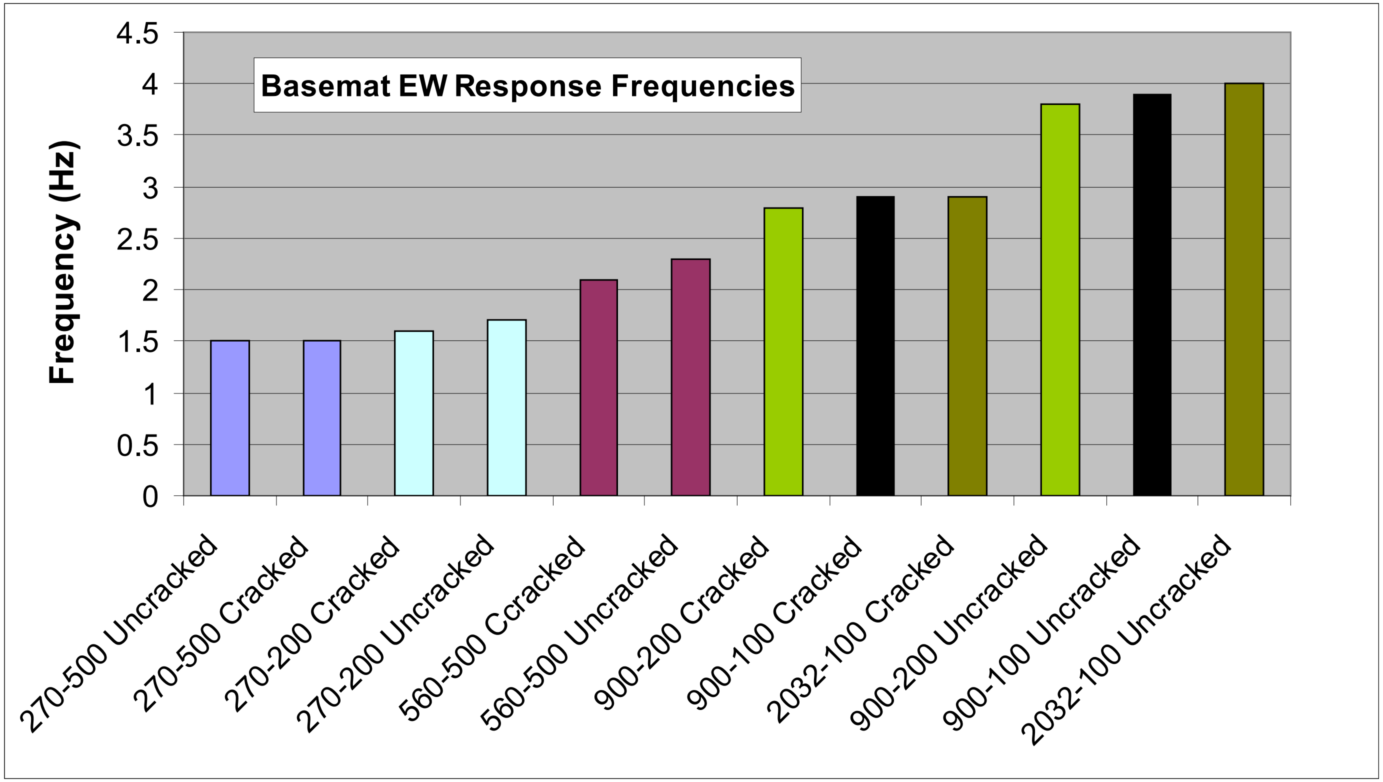
3. SSI Responses from updated set of R/B Complex SSI analyses in TR MUAP-10006 Revision 2, Section 4.1:

✓ Site-independent SSI analyses cover a wide range of responses of R/B Complex in NS direction



3. MUAP-10006 Revision 2

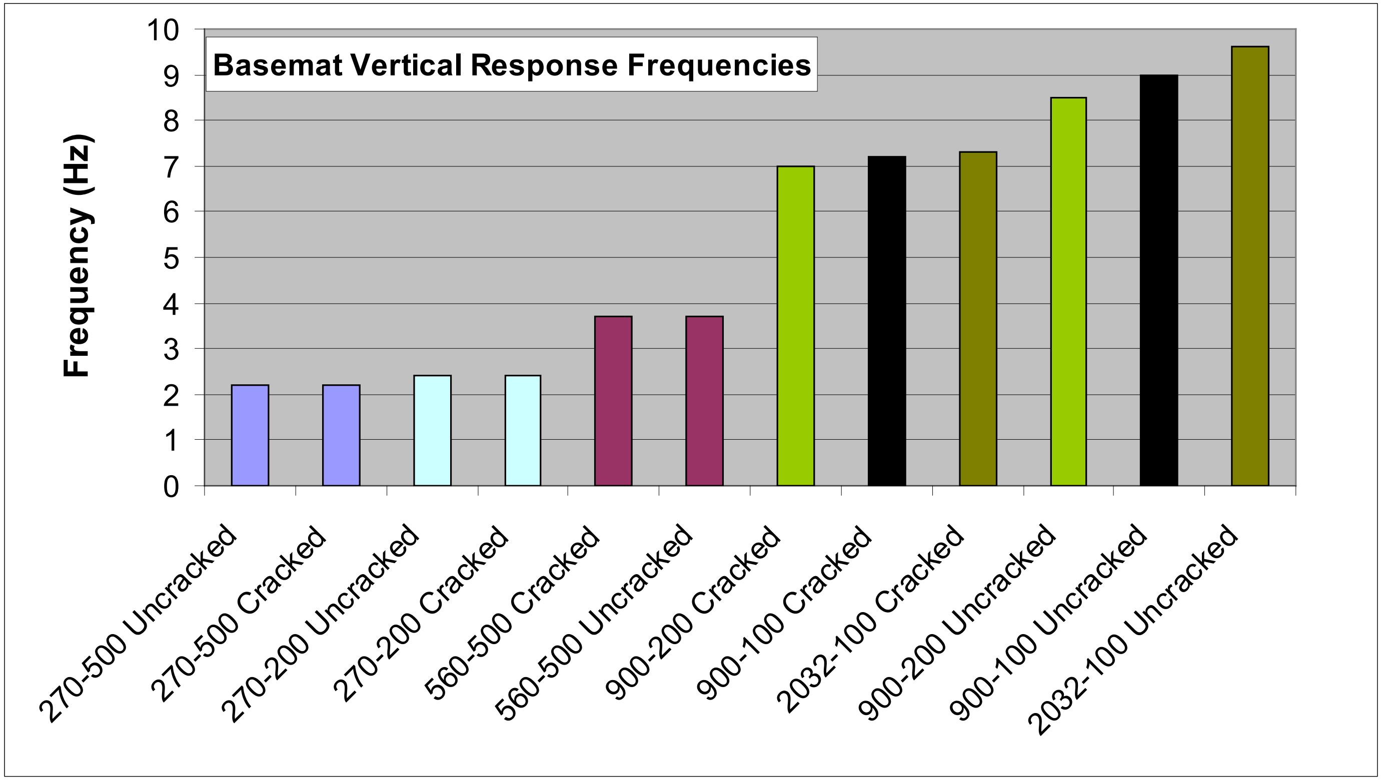
3. **SSI Responses from updated set of R/B Complex SSI analyses in TR MUAP-10006 Revision 2, Section 4.1:**
   - ✓ Site-independent SSI analyses cover a wide range of responses of R/B Complex in EW direction



3. MUAP-10006 Revision 2

3. **SSI Responses from updated set of R/B Complex SSI analyses in TR MUAP-10006 Revision 2, Section 4.1:**

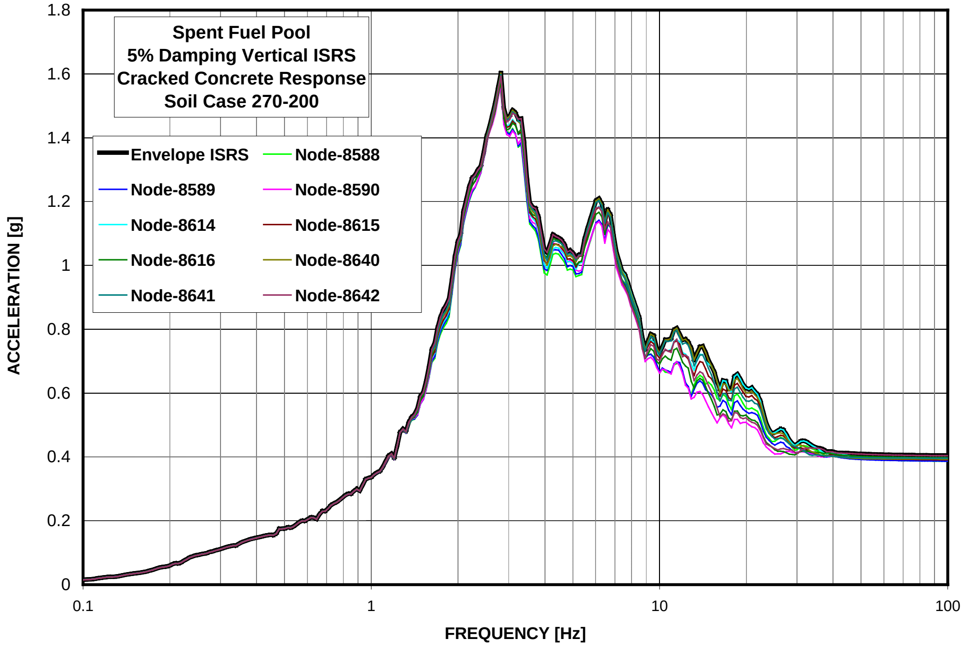
✓ Site-independent SSI analyses cover a wide range of responses of R/B Complex in vertical direction



4. Updated Standard Design Basis ISRS in TR MUAP-10006 Revision 2, Section 3.2, Section 4.2:

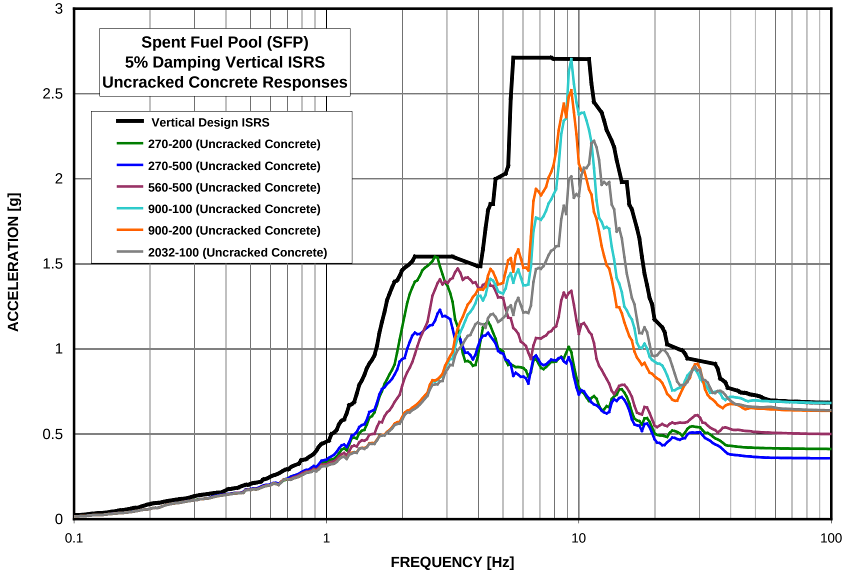
- ✓ Standard Design Basis ISRS developed by enveloping the responses at several nodes at particular location where the equipment is supported in order to capture response variations and/or rotation effects Appendices A and B define the nodal grouping utilized for development of ISRS

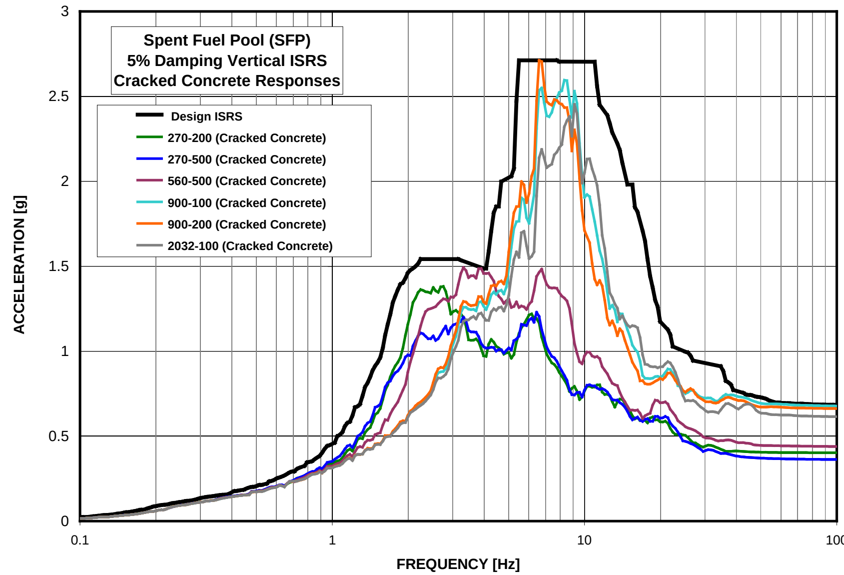
	Node No	Coordinates (ft)		
		x	y	z
SFP Vertical ISRS	8588	1179	3363	2525
	8589	1179	3883	2525
	8590	1179	4675	2525
	8614	12524	3363	2525
	8615	12524	3883	2525
	8616	12524	4675	2525
	8640	13257	3363	2525
	8641	13257	3883	2525
	8642	13257	4675	2525



4. Updated Standard Design Basis ISRS in TR MUAP-10006 Revision 2, Section 3.2, Section 4.2:

- ✓ The envelope of responses of models with two bounding stiffness and damping properties for six generic site conditions yield Design Basis ISRS with broad band frequency content





5. Reason and Impact of the Revision of Generic Site Profiles Database in MUAP-10006 Revision 2

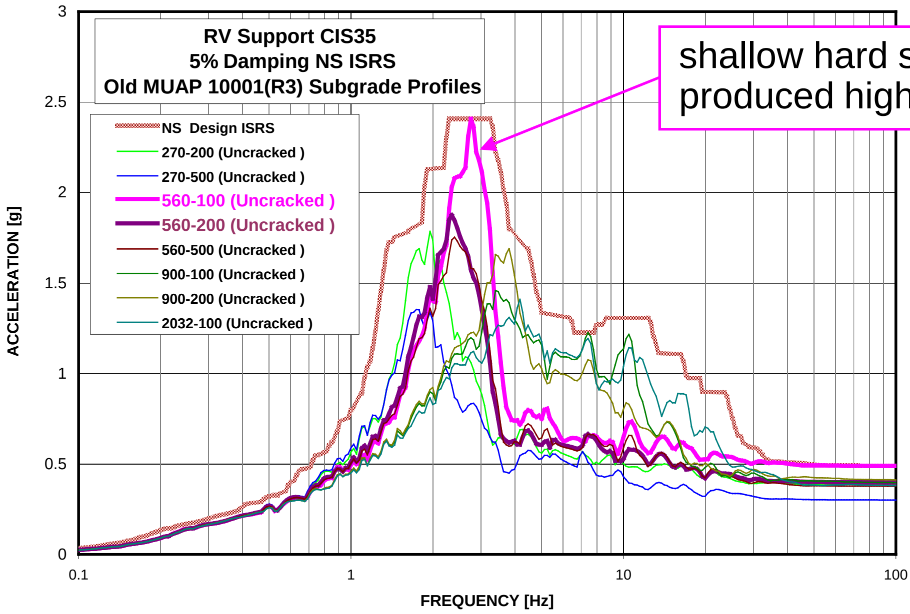
- ✓ Site Profiles 560-100 and 560-200 are deleted from the standard design database because:
  - These shallow generic hard site profiles produced high peak SSI responses in the lower frequency range
  - Sharp peak responses are the result of the reduced SSI geometric damping due to reflection of waves at soil-rock base interface
  - The design ISRS peaks in the 2 to 3 Hz range imposed challenges to the design of Reactor Vessel (RV) components
- ✓ Revisions of Generic Profiles Database has a relatively small impact on the ability of site-independent SSI analyses to capture a wide range of SSI frequencies response
- ✓ Replacement in the MUAP-10001 Revision 4 of the ground motion time histories in the standard design database resulted in similar design ISRS

3. MUAP-10006 Revision 2

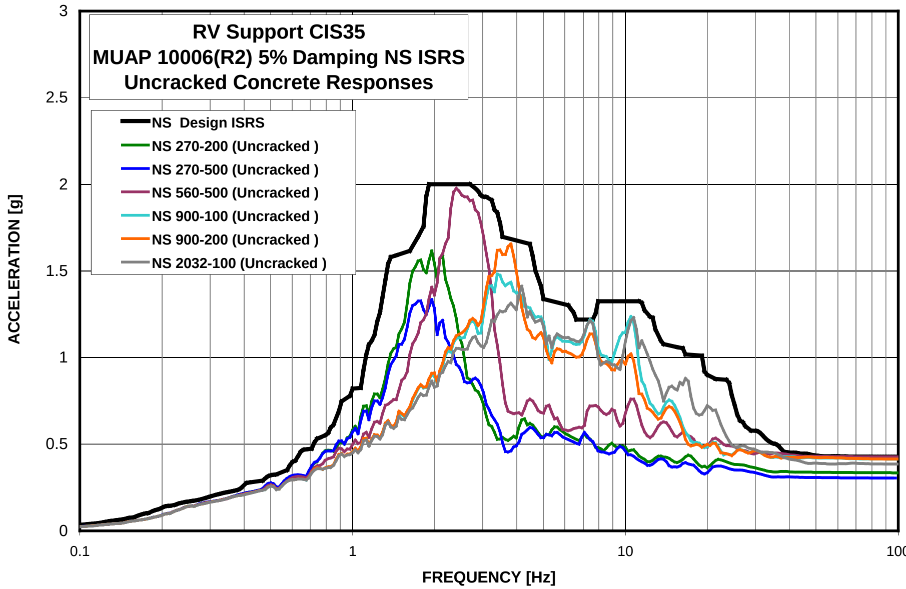
➢ Reason for removal of Profiles 560-100 and 560-200

✓ RV Support NS ISRS

Responses of R/B Complex FEM with uncracked concrete properties based on revised ground motion input



shallow hard soil profiles 560-100 and 560-200 produced high peak SSI responses in 2 to 4 Hz range



5. Impact of the Revision of Generic Site Profiles Database in MUAP-10006 Revision 2

- ✓ The SSI frequencies extracted from acceleration transfer functions for responses at center of R/B Complex basemat bottom are compared to assess the impact of the revisions made on the site profiles database
- ✓ Comparisons show that the removal of the two generic profiles (560-100 and 560-200) has a relatively small impact on the ability of site-independent SSI analyses to capture a wide range of SSI frequencies
- ✓ Revisions of the other generic site profiles resulted in minor shifts of SSI frequencies for the particular site condition considered

3. MUAP-10006 Revision 2

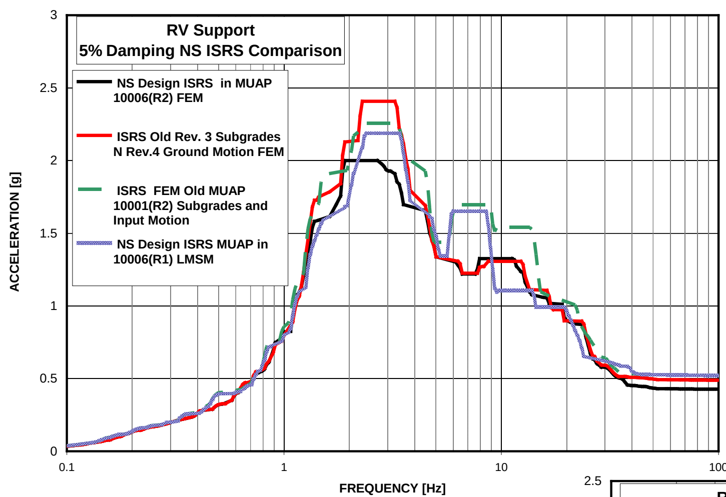
➤ Comparison of Peak Frequencies of Response at SSI Interface

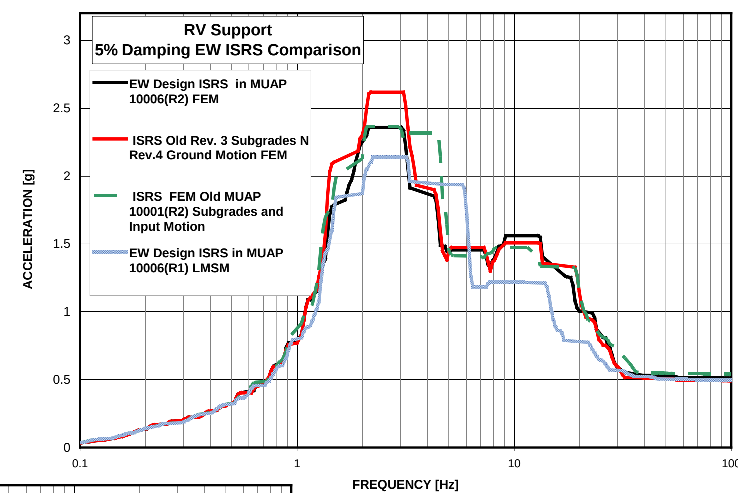
Soil Profile	Current Profiles			Revised Profiles		
	Peak Frequency (Hz)			Peak Frequency (Hz)		
	NS	EW	Vertical	NS	EW	Vertical
270-500 Cracked	**1.6**	**1.6**	**1.6**	**1.5**	**1.5**	**2.2**
270-500 Uncracked	**1.7**	**1.6**	**1.6**	**1.6**	**1.5**	**2.2**
270-200 Cracked	**1.8**	**1.7**	**2.9**	**1.7**	**1.6**	**2.4**
270-200 Uncracked	**1.8**	**1.8**	**2.9**	**1.8**	**1.7**	**2.4**
560-500 Cracked	**2.1**	**2.0**	**3.2**	**2.2**	**2.1**	**3.7**
560-500 Uncracked	**2.3**	**2.2**	**3.3**	**2.4**	**2.3**	**3.7**
560-200 Cracked	**2.1**	**2.0**	**3.3**	**Removed**		
560-200 Uncracked	**2.2**	**2.1**	**3.4**			
560-100 Cracked	**2.3**	**2.2**	**4.5**			
560-100 Uncracked	**2.7**	**2.6**	**4.5**			
900-200 Cracked	**2.8**	**2.8**	**7.0**	**2.8**	**2.8**	**7.0**
900-200 Uncracked	**3.8**	**3.8**	**8.3**	**3.9**	**3.8**	**8.5**
900-100 Cracked	**2.9**	**2.9**	**7.3**	**2.9**	**2.9**	**7.2**
900-100 Uncracked	**3.9**	**3.9**	**9.3**	**3.9**	**3.9**	**9.0**
2032-100 Cracked	**2.9**	**2.9**	**7.3**	**2.9**	**2.9**	**7.3**
2032-100 Uncracked	**4.1**	**4.0**	**9.4**	**4.1**	**4.0**	**9.6**

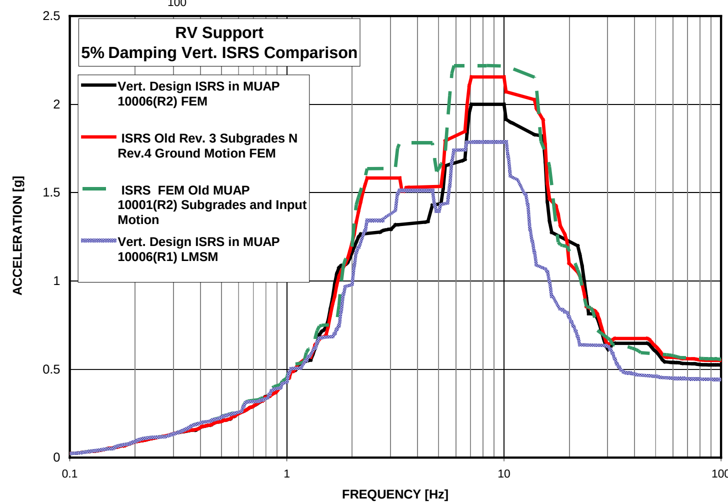
3. MUAP-10006 Revision 2

5. Impact of the Revision of Generic Site Profiles Database in MUAP-10006 Revision 2

- ✓ Replacement of ground motion time histories did not reduce the critical peak responses in the RV Support design ISRS







3. MUAP-10006 Revision 2

6. Updated Maximum Seismic Displacements in TR MUAP-10006 Revision 2, Section 3.2, Section 4.2:

✓ Consideration of reduced (cracked concrete) stiffness and the ability of dynamic FE models to capture local responses result in higher magnitudes of seismic displacements

Maximum Displacements of PCCV Relative to Free-field Motion

	Lumped Mass Stick Model - MUAP-10006(R1)			FE Model - MUAP-10006(R2)		
Symbol	Elevation (ft)	X-NS Disp. (in)	Y-EW Disp. (in)	Elevation (ft)	X-NS Disp. (in)	Y-EW Disp. (in)
CV07	145.58	1.29	1.55	145.58	1.95	2.14
CV06	115.50	1.11	1.27	113.38	1.64	1.83
CV05	92.17	0.97	1.06	99.81	1.52	1.69
CV04	76.42	0.87	0.92	86.25	1.40	1.56
CV03	68.25	0.81	0.84	68.22	1.24	1.38
CV02	50.17	0.69	0.68	50.18	1.08	1.21
CV01	25.25	0.53	0.50	32.15	0.93	1.03

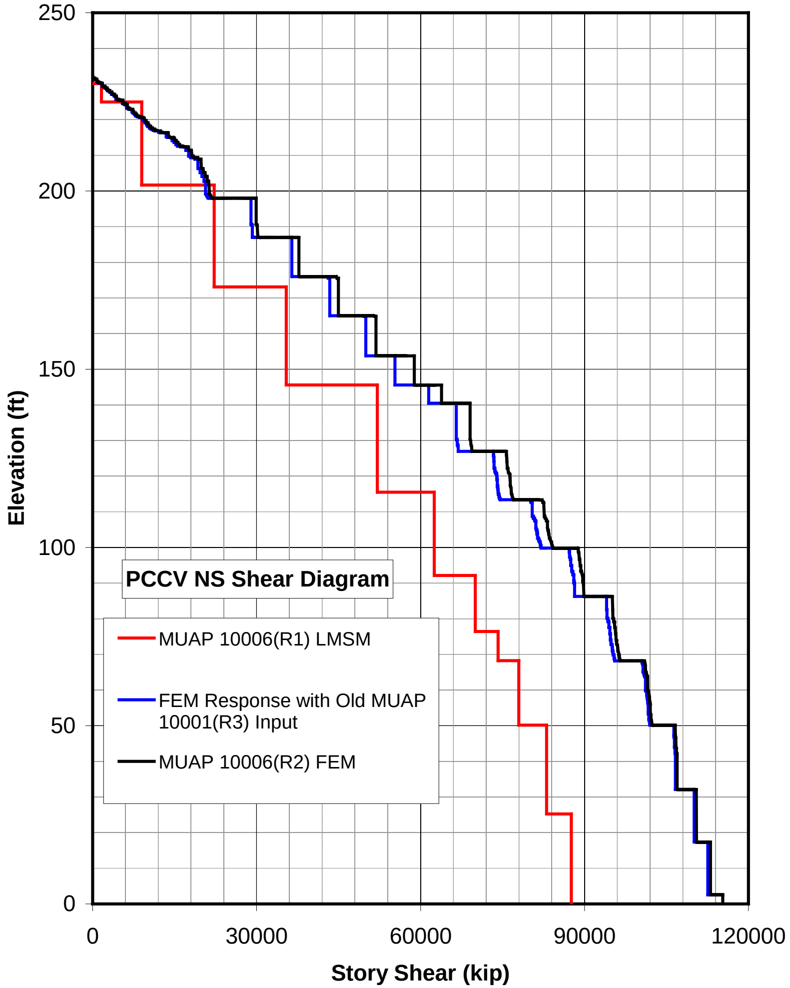
7. Updated SSE Loads in TR MUAP-10006 Revision 2, Section 3.2 (Methodology) and Section 4.2 (Results):

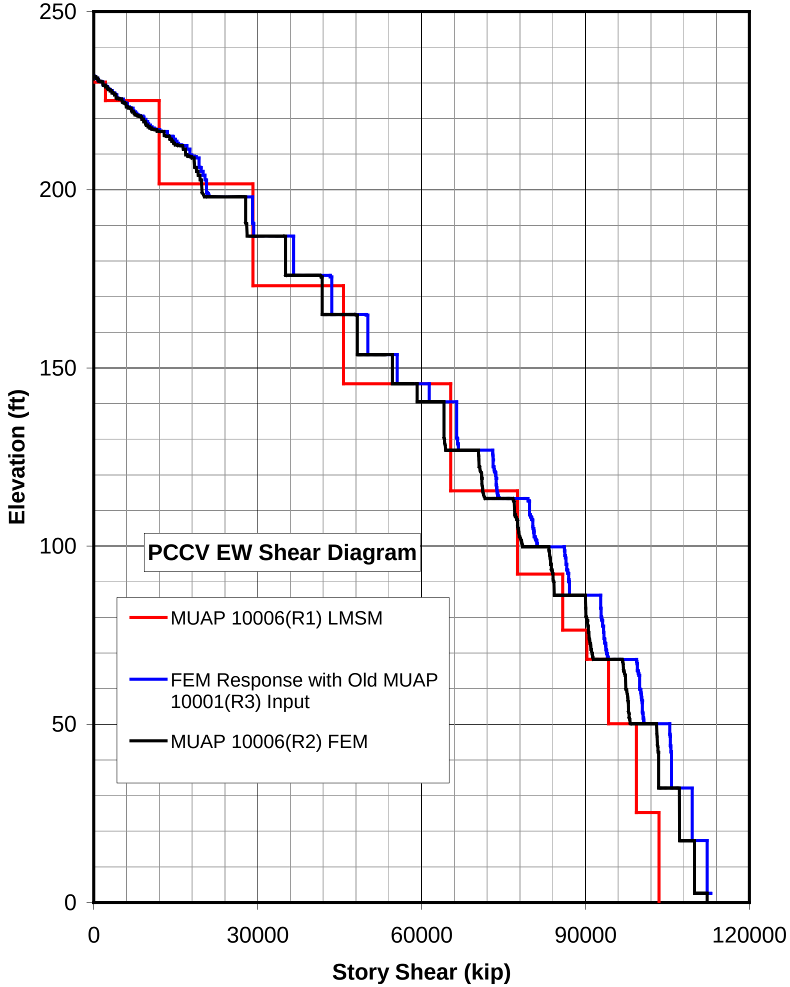
- ✓ The SSE design loads from the updated MUAP-10006(R2) SSI analyses of FEM are higher magnitude than those obtained from SSI analyses of LMSM in MUAP-10006(R1)
- ✓ The magnitudes of MUAP-10006(R2) SSE design loads in the two horizontal directions are more consistent than those specified in MUAP-10006(R1)
- ✓ Revisions of generic subgrade profiles and input ground motion time histories in the MUAP-10001(R4) seismic design database have a negligible effect on the magnitudes of SSE design loads and the standard design of R/B Complex and PS/B structural members

3. MUAP-10006 Revision 2

➢ PCCV SSE Design Loads Shear Diagrams

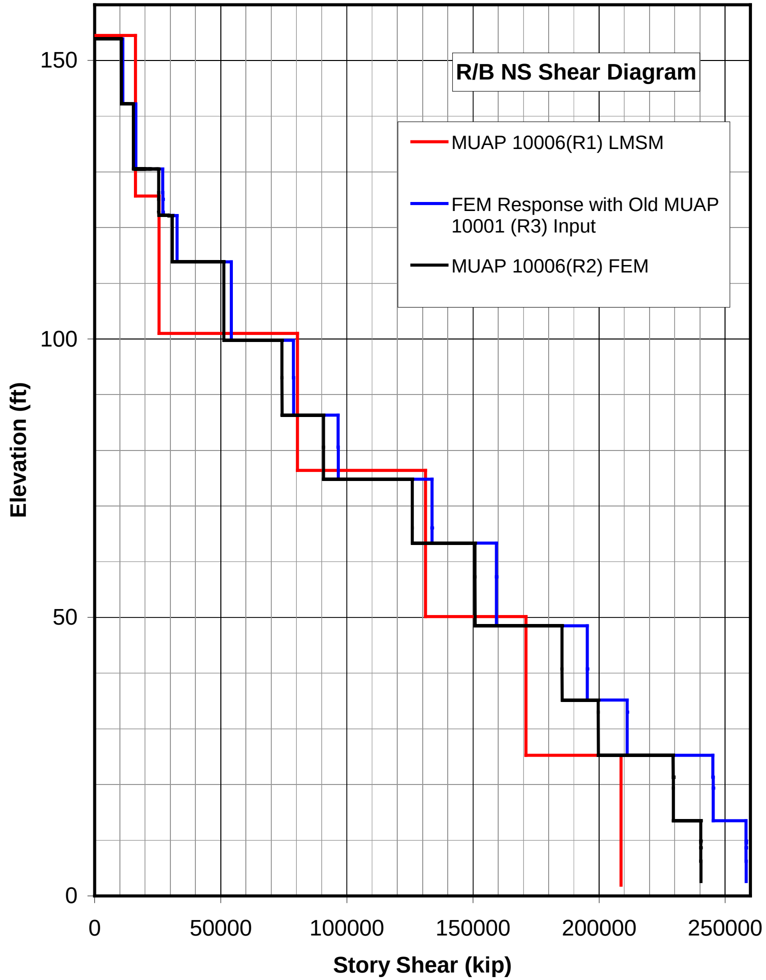
(SSE loads developed from envelope of uncracked and cracked concrete responses)

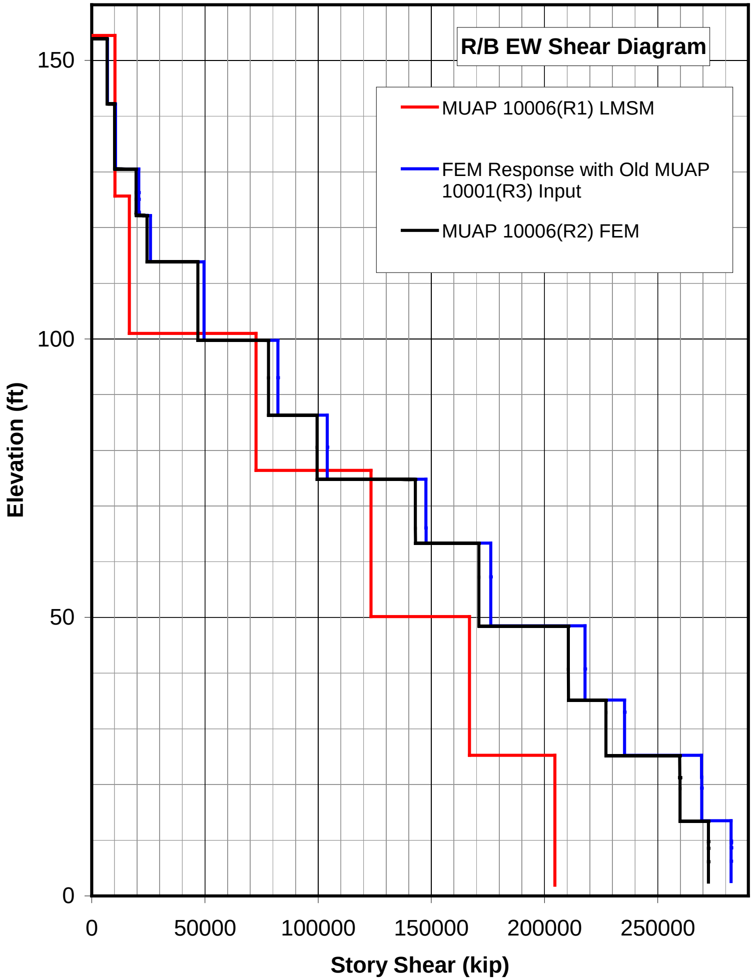




➢ R/B SSE Design Loads Shear Diagrams

(SSE loads developed from cracked concrete responses)

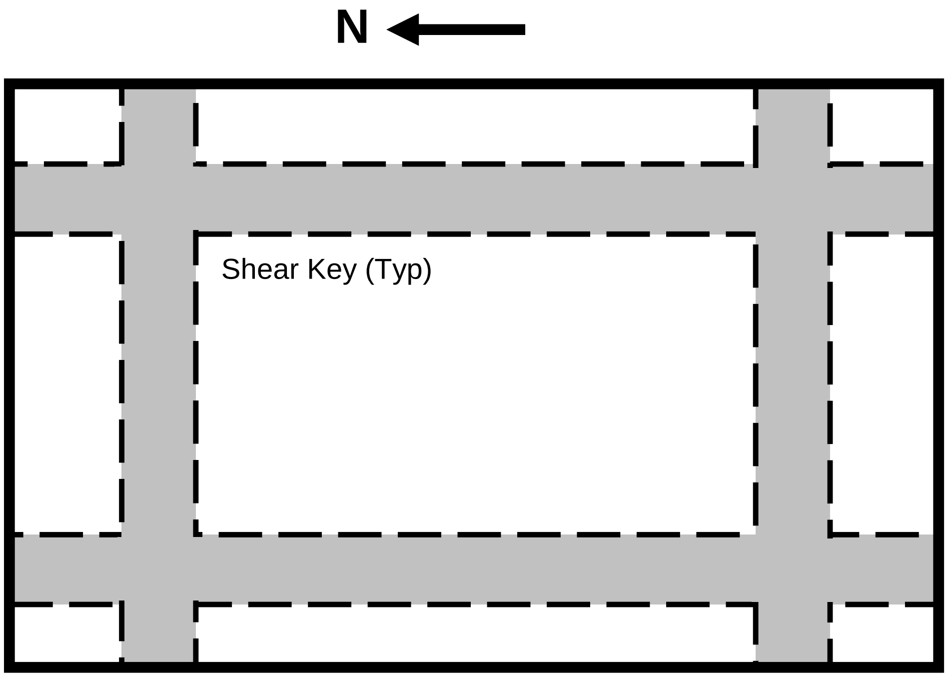




8. Sliding Stability Evaluations presented in TR MUAP-10006 Revision 2, Section 4.6 and Appendix K:

- ✓ Stability evaluation and soil bearing pressure demand calculations are based on responses obtained from site-independent SSI analyses of design basis R/B Complex and PS/B Dynamic Finite Element Models (FEM's)
- ✓ Safety Factors for sliding and overturning stability as well as the maximum soil bearing pressures are calculated for each time step of the input design motion excitations
- ✓ Seismic driving forces due to each component of earthquake are combined for each time step based on quasi-static approach using SSI analysis results for time histories of nodal acceleration (R/B Complex) or spring forces (PS/B)
- ✓ In order to meet the SRP 3.8.5 requirement for stability safety factors of 1.1, shear keys are designed to improve the sliding resistance of the R/B Complex foundation
- ✓ In order to meet the SRP 3.8.5 requirement for stability safety factor of 1.1, a ballast constructed of concrete is designed to improve the sliding and overturning resistance of the PS/B foundation

- **Shear Key Plan Layout for R/B Complex Foundation**



➢ R/B Complex Stability Results with Shear Keys

Site	Minimum Sliding Factor of Safety	Max Bearing Pressure (ksf)	Minimum Overturning Factor of Safety
270-200	1.15	31	1.61
270-500	1.58	26	1.86
560-500	1.18	43	1.38
900-100	1.21	47	1.27
900-200	1.15	52	1.25
2032-100	1.27	38	1.37

4. Summary

- ✓ TR MUAP-10001(R4) and MUAP-10006(R2) document the latest revisions of the standard seismic design basis methodology and results
- ✓ US-APWR standard seismic design is based entirely on the results of site-independent SSI analyses of Dynamic FE Models
- ✓ Effects of concrete cracking on seismic response are captured by considering two bounding levels of structural stiffness and damping properties
- ✓ The database of generic subgrade profiles has been modified to lower peak ISRS response in lower frequency range that adversely affect the design of Reactor Vessel components
- ✓ The revisions of the database of generic subgrade profiles and time histories have a negligible effect on the structural design loads and applicability of the standard design for majority of candidate sites
- ✓ The revisions of input design motion time histories do not result in reduction of critical peaks in design basis ISRS

4. Summary

- ✓ Revised set of site-independent SSI analyses of FE models with two bounding stiffness and damping properties for six generic profiles provide:
  - Broad frequency band ISRS that more accurately represent the seismic demands for standard design and evaluation of SSC's
  - Higher amplitude maximum seismic displacements
  - SSE loads with higher magnitudes
- ✓ Stability evaluation and soil bearing pressure demands calculations are based on SSI responses from dynamic FE models
- ✓ Shear keys are designed to improve the sliding stability of R/B Complex foundation
- ✓ Ballast under the PS/B foundations ensures the sliding and overturning stability of PS/B

US-APWR

MUAP-11007

Embedment and Ground Water Effects on SSI

November 7, 2011

Mitsubishi Heavy Industries, Ltd.

Contents

- Overall Report Changes
  - Report Title – Revised to Align With Scope
  - Stability Results - Moved to MUAP-10006

Contents

A. Effect of Embedment on Seismic SSI Response

1. Purpose and Contents of Report
2. Results
3. Conclusion

B. Ground Water Table Effects on Seismic SSI Response

1. Purpose and Contents of Report
2. Results
3. Conclusion

A. Effect of Embedment on SSI

1. Purpose and Contents of Report

Purpose

Quantify the effects of embedment on the SSI response of the R/B Complex

A. Effects of Embedment on SSI

<u>Contents of Report</u>

- Updated LMSM used for embedment effects
- Five soil profiles analyzed
- Previous (MUAP-10001 Rev. 3) soil profiles used
- Previous (MUAP-10001 Rev. 3) seismic time histories used

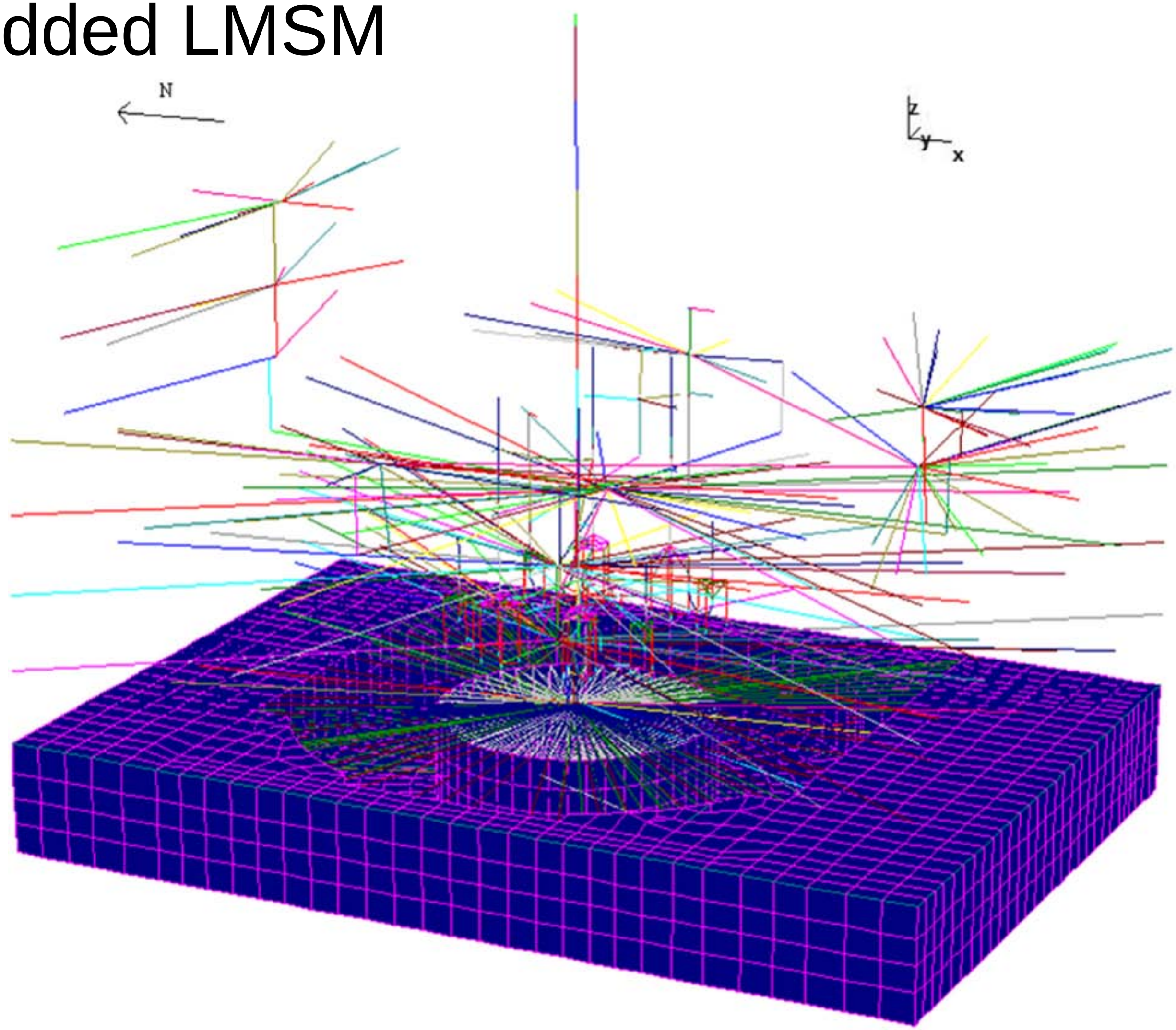
Analysis Cases

Structure Stiffness Condition	Surface Supported or Embedded				Generic Site Profile				
	Surface supported	0-sided embed	2-sided embed	4-sided embed	270-200	560-100	900-100	900-200	2032-100
Cracked	X				X				
Cracked	X					X			
Uncracked	X						X		
Uncracked	X							X	
Uncracked	X								X
Cracked		X			X	X			
Cracked			X		X	X			
Cracked				X	X	X			
Uncracked			X				X		
Uncracked			X					X	
Uncracked			X						X

Previous Study (uncracked)

A. Effects of Embedment on SSI

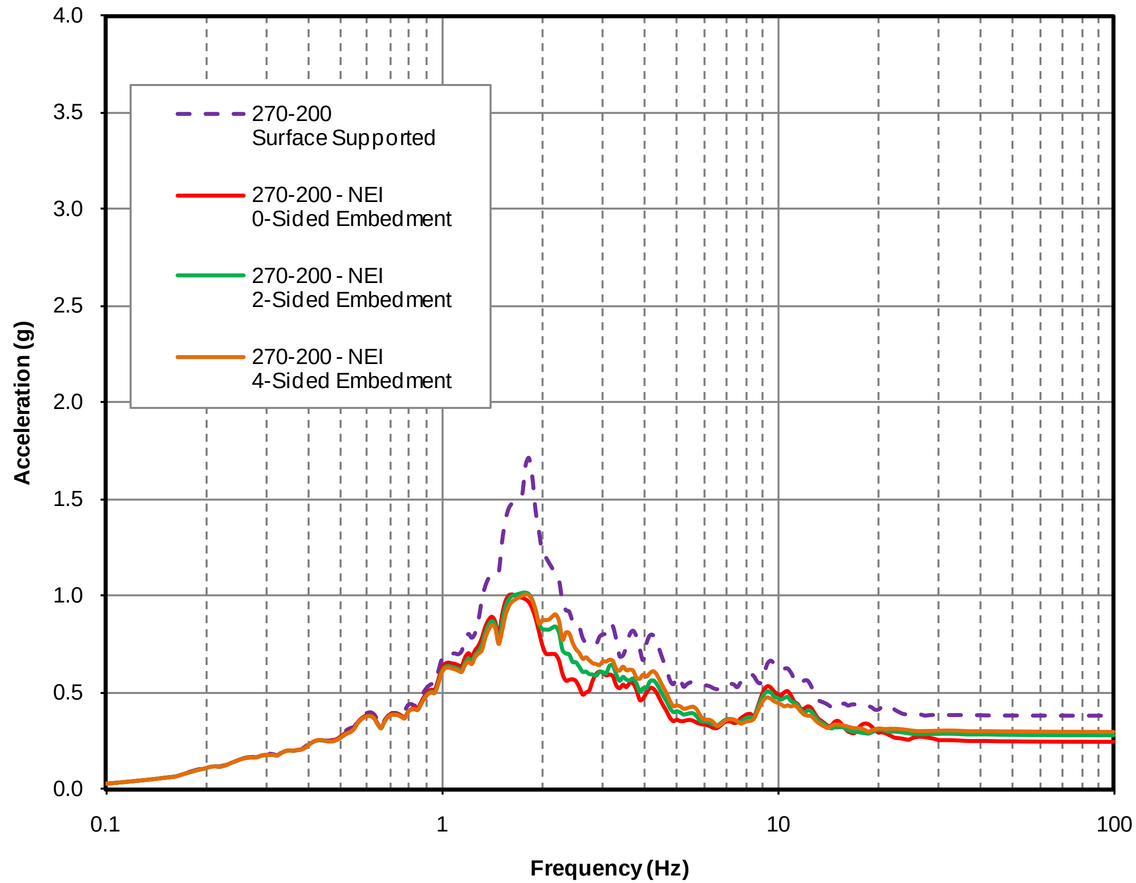
Embedded LMSM



A. Effects of Embedment on SSI

2. Results

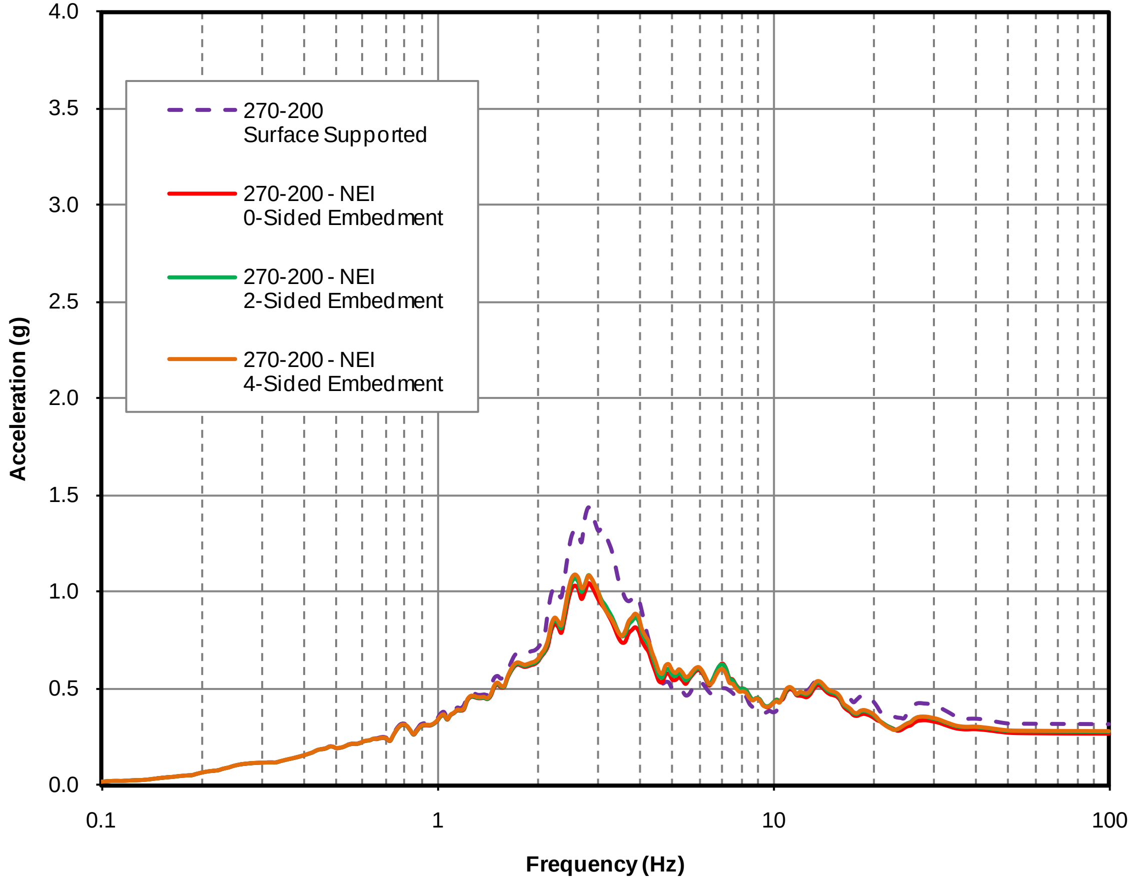
Comparison of 5%-Damped ISRS results for North-South (NS) Response at top of Containment Foundation



MITSUBISHI HEAVY INDUSTRIES, LTD.

A. Effects of Embedment on SSI

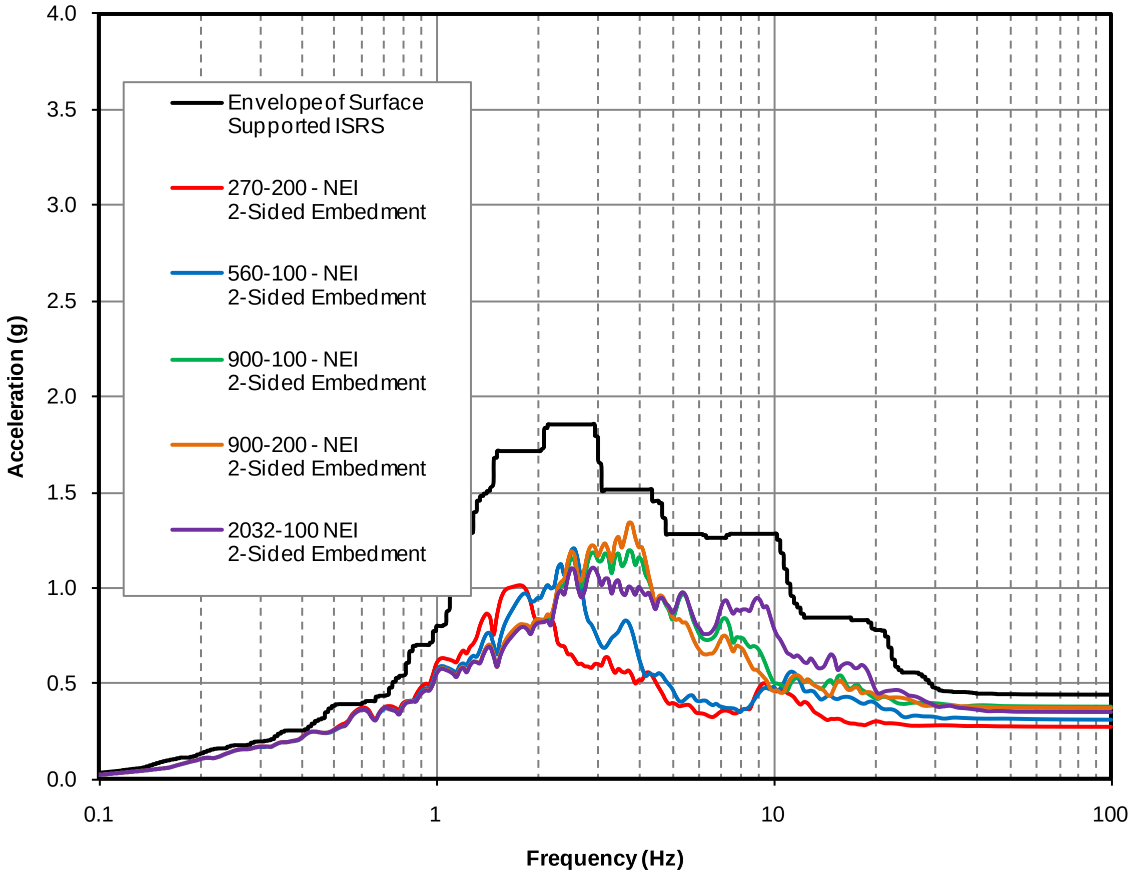
Comparison of 5%-Damped ISRS results for Vertical Response at top of Containment Foundation



MITSUBISHI HEAVY INDUSTRIES, LTD.

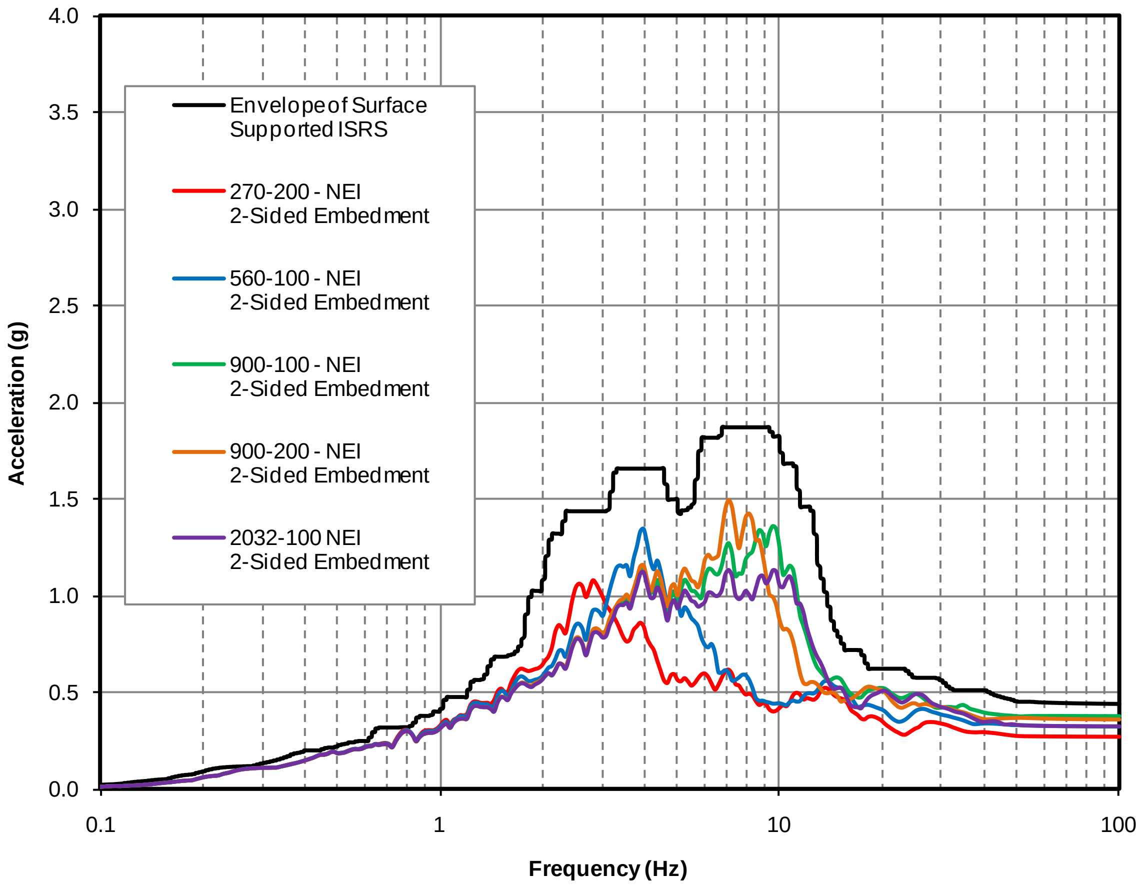
A. Effects of Embedment on SSI

Comparison of 5%-Damped ISRS results of all Embedment Cases versus Envelope for North-South (NS) Response at top of Containment Foundation



A. Effects of Embedment on SSI

Comparison of 5%-Damped ISRS results of all Embedment Cases versus Envelope for Vertical Response at top of Containment Foundation



A. Effects of Embedment on SSI

3. Conclusion

- For the five generic soil profiles studied, variations in the seismic response for the embedded foundation condition are covered by the seismic response envelopes assuming a surface-supported foundation condition

- The seismic response is relatively insensitive to the 4, 2, and 0-sided embedment conditions analyzed

- The major effect of embedment is produced by the changes in the free-field seismic input motion to the SSI system due to the presence of the top 40-feet of overburden soil layer above the R/B basemat

- The approach in MUAP-10006 Rev. 2 which utilizes surface mounted structures is conservative for SSI analysis

B. Effects of Ground Water Table

1. Purpose and Contents of Report

<u>Purpose</u>

US-APWR Standard Plant Structures SSI analyses consider the structures as surface mounted with ground water one (1) foot below finished grade

The actual ground water level may fluctuate from the design value

To quantify the effects of ground water fluctuations on the SSI response of R/B Complex and the PS/B

B. Effects of Ground Water Table

Contents of Report

- Updated FEM used for ground water effect
- Two softest soil profiles analyzed
- Previous (MUAP-10001 Rev. 3) soil profiles used
- Previous (MUAP-10001 Rev. 3) seismic time histories used

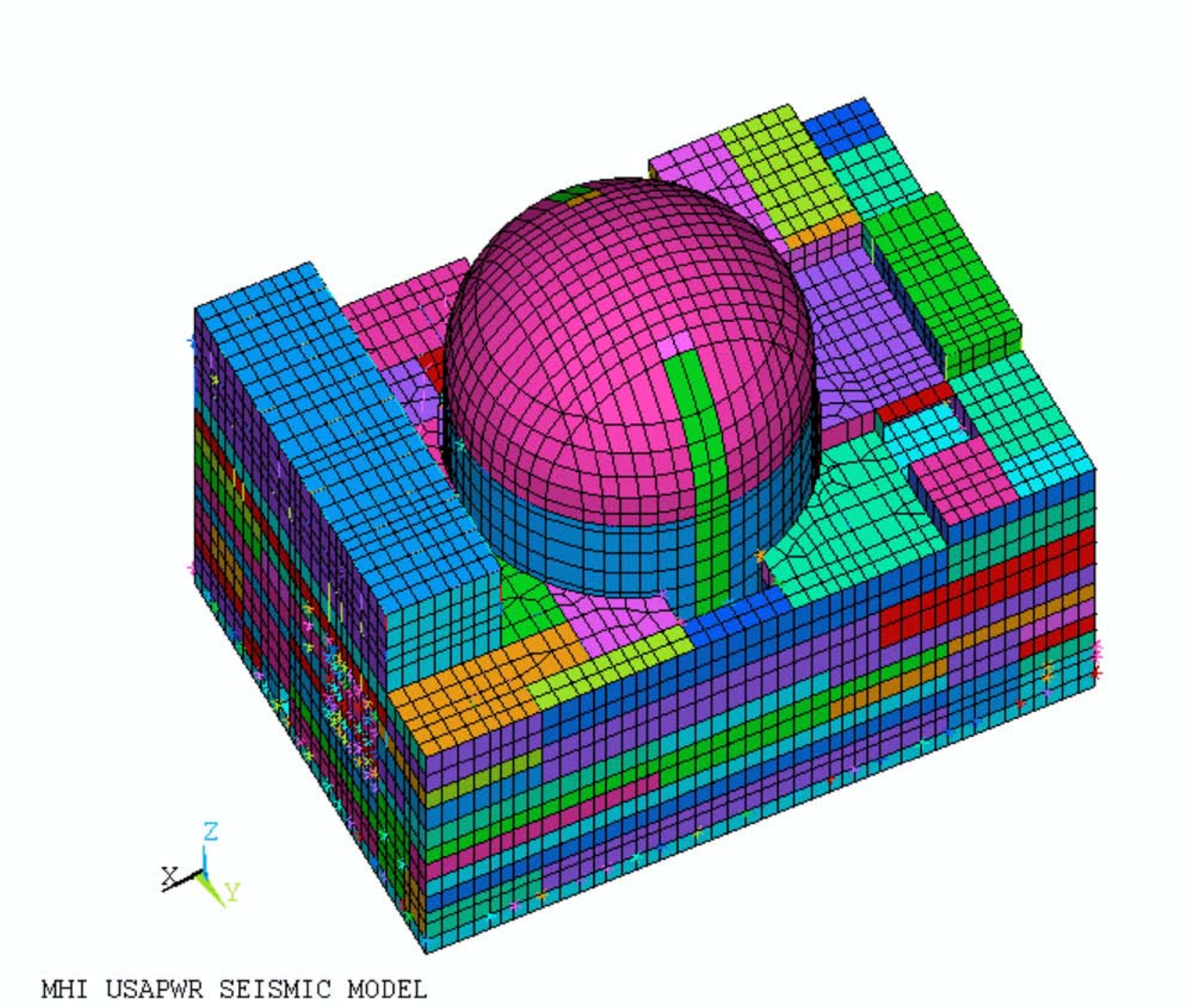
B. Effects of Ground Water Table

Analysis Cases

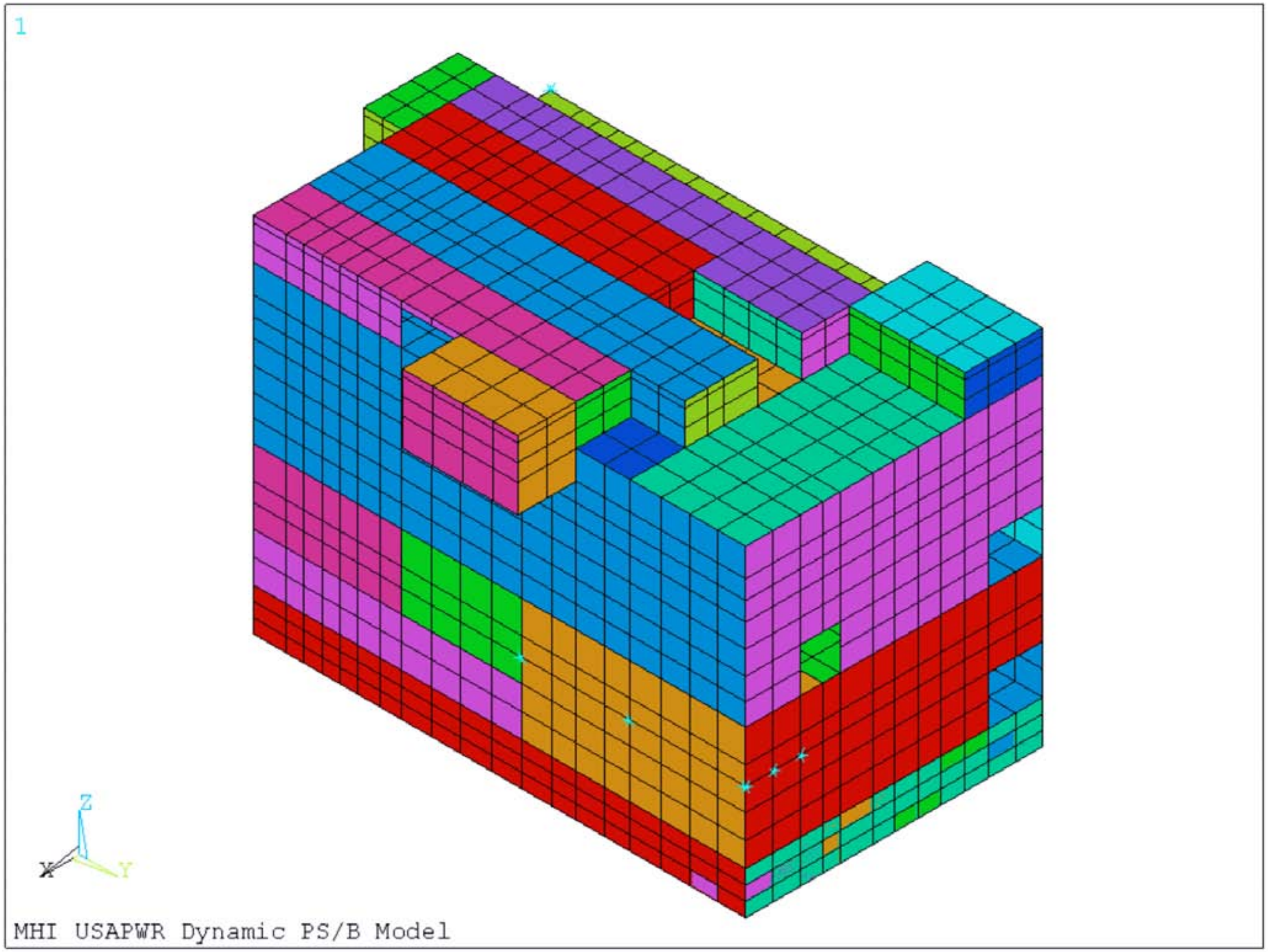
- Two Softest Soil Profiles are Sensitive
  - ✓ 270-200 Saturated and Unsaturated
  - ✓ 560-100 Saturated and Unsaturated
- Unsaturated Profiles Derived from Saturated Profiles

B. Effects of Ground Water Table

R/B Complex FEM



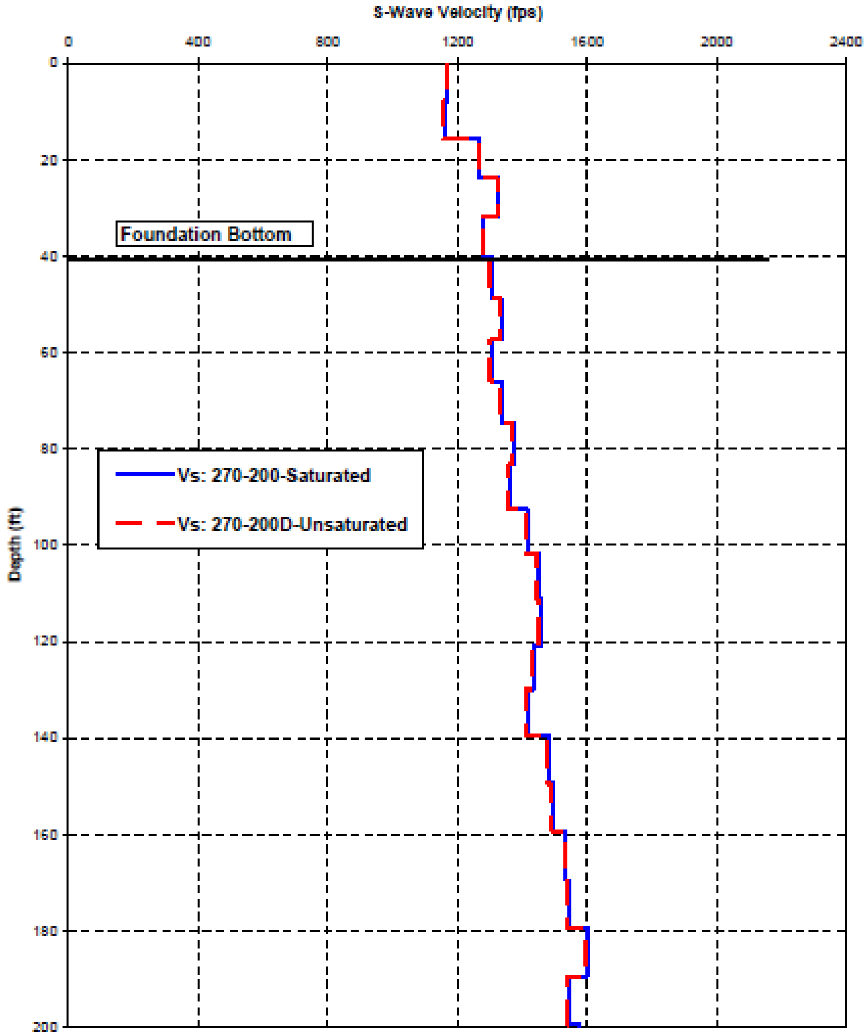
PS/B FEM



B. Effects of Ground Water Table

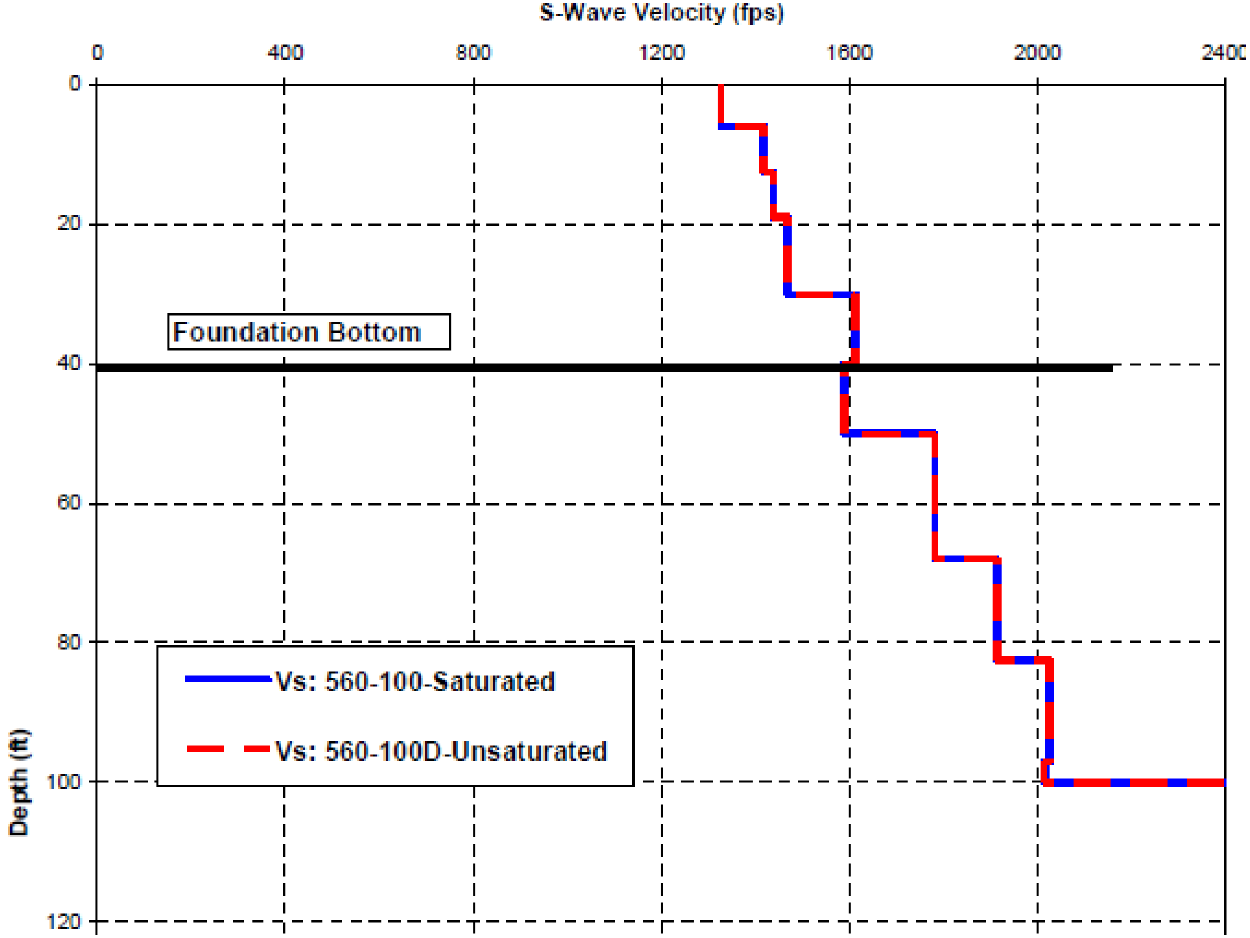
2. Results

Strain Compatible Shear Wave Velocities 270-200



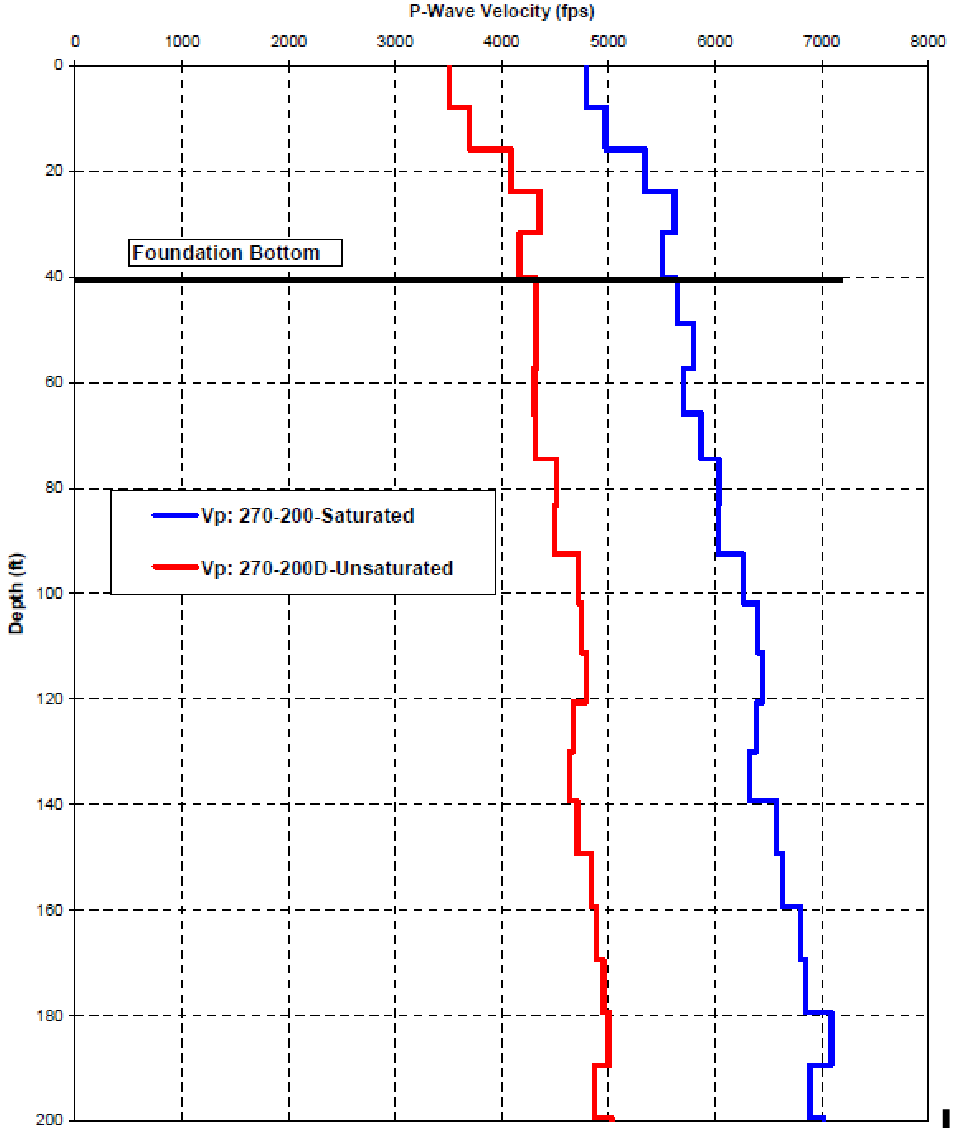
B. Effects of Ground Water Table

Strain Compatible Shear Wave Velocities 560-100



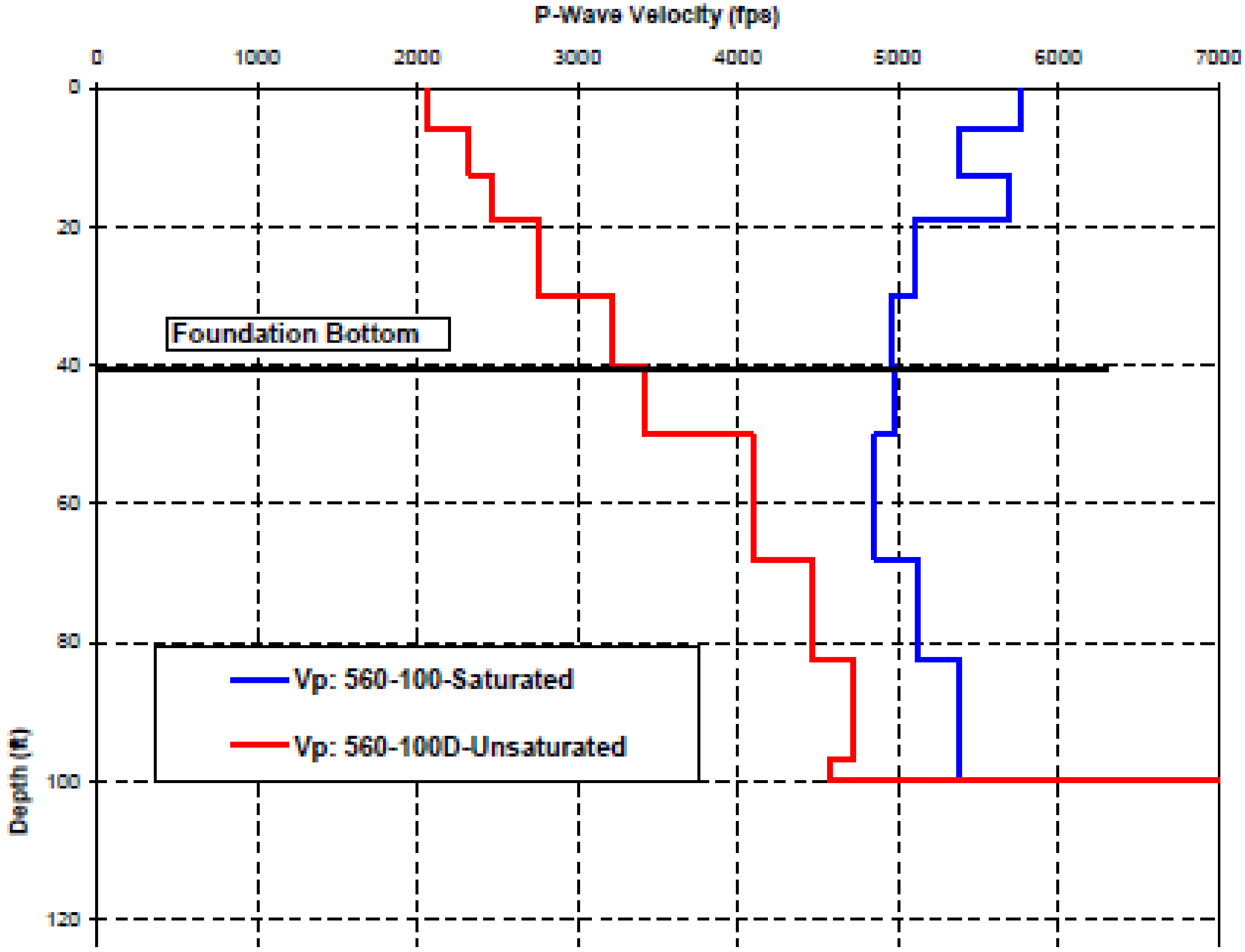
B. Effects of Ground Water Table

Strain Compatible Compression Wave Velocities 270-200



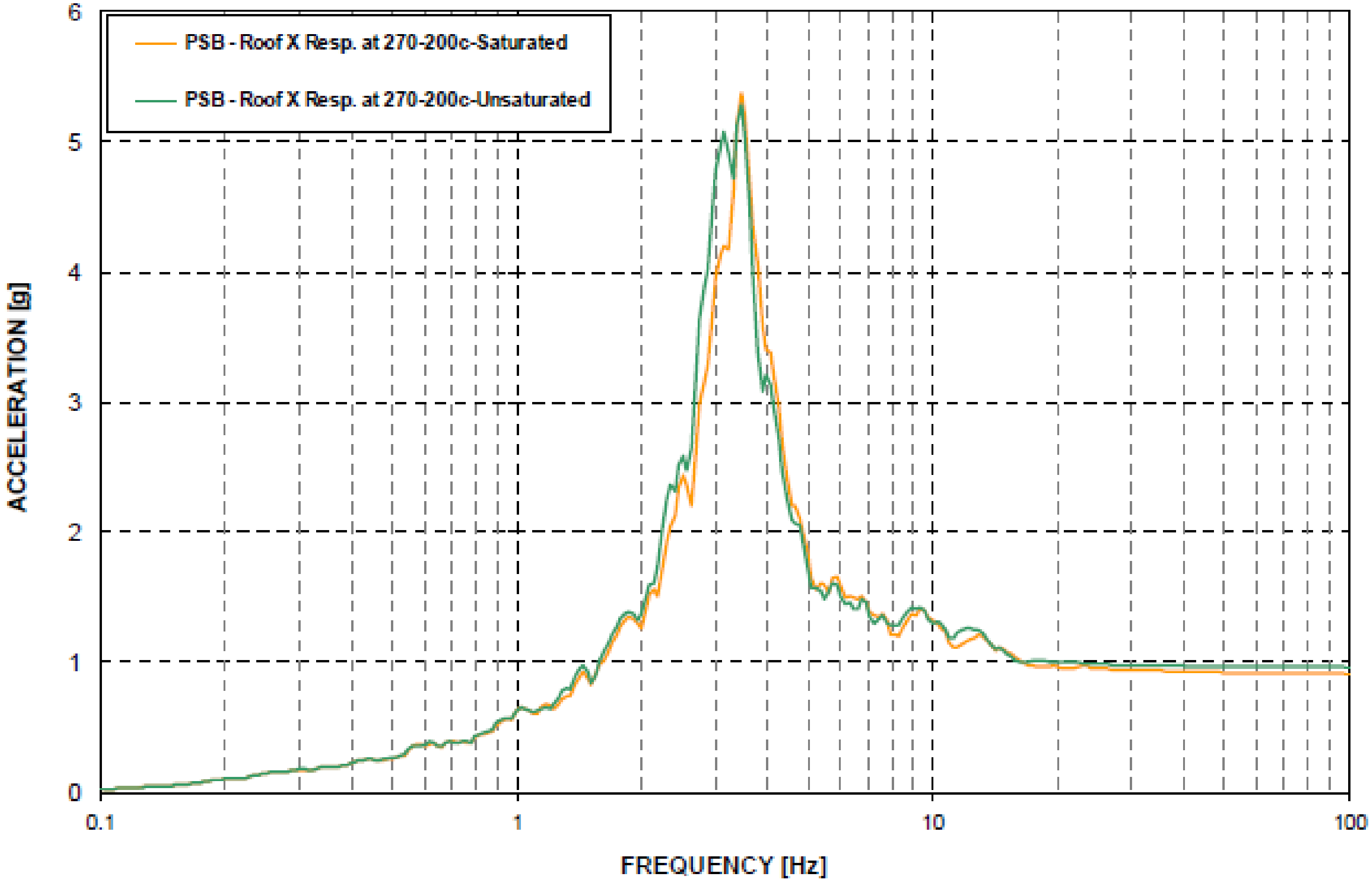
B. Effects of Ground Water Table

Strain Compatible Compression Wave Velocities 560-100



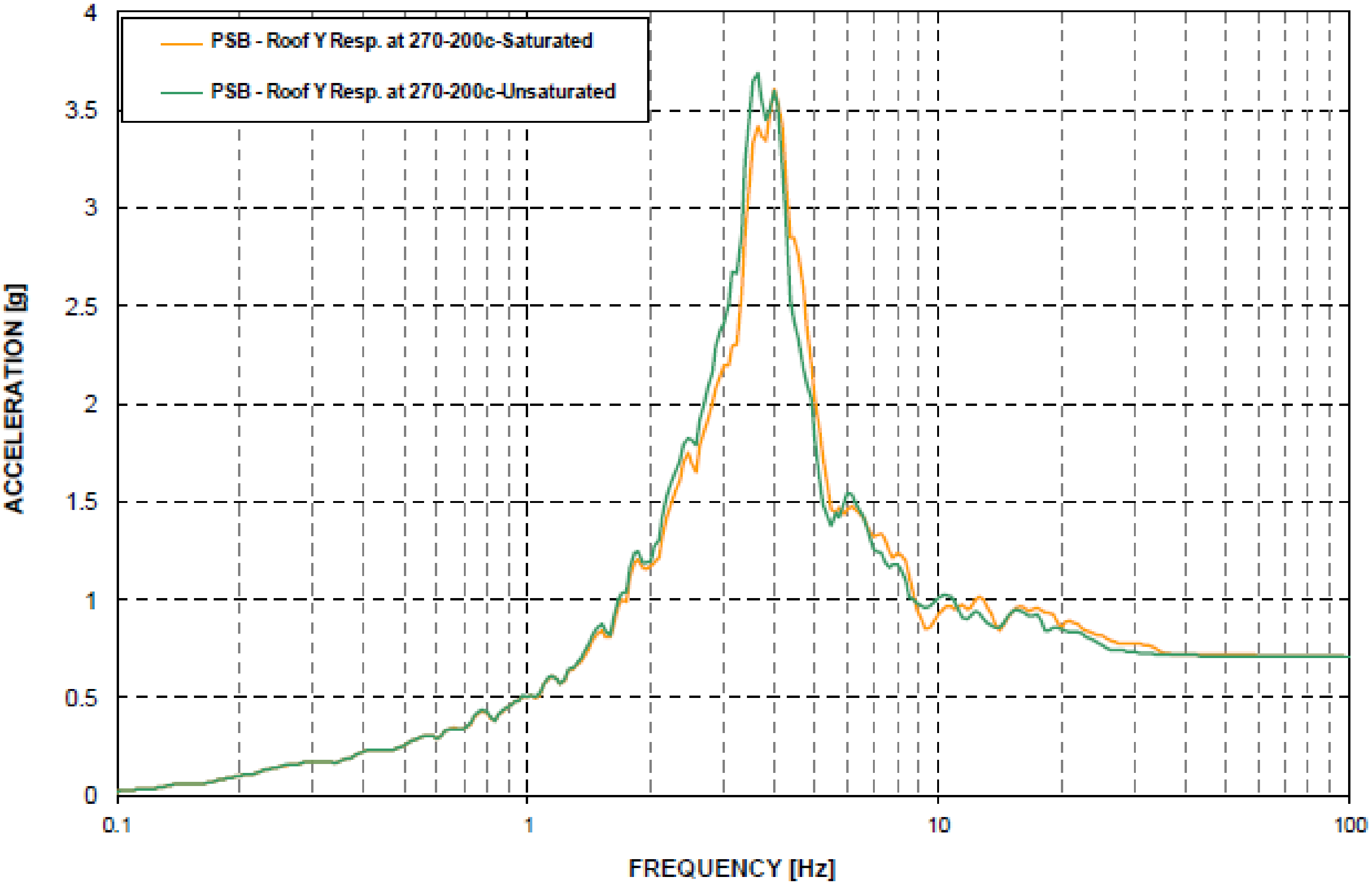
B. Effects of Ground Water Table

PS/B Roof N-S ISRS 270-200 and 270-200D



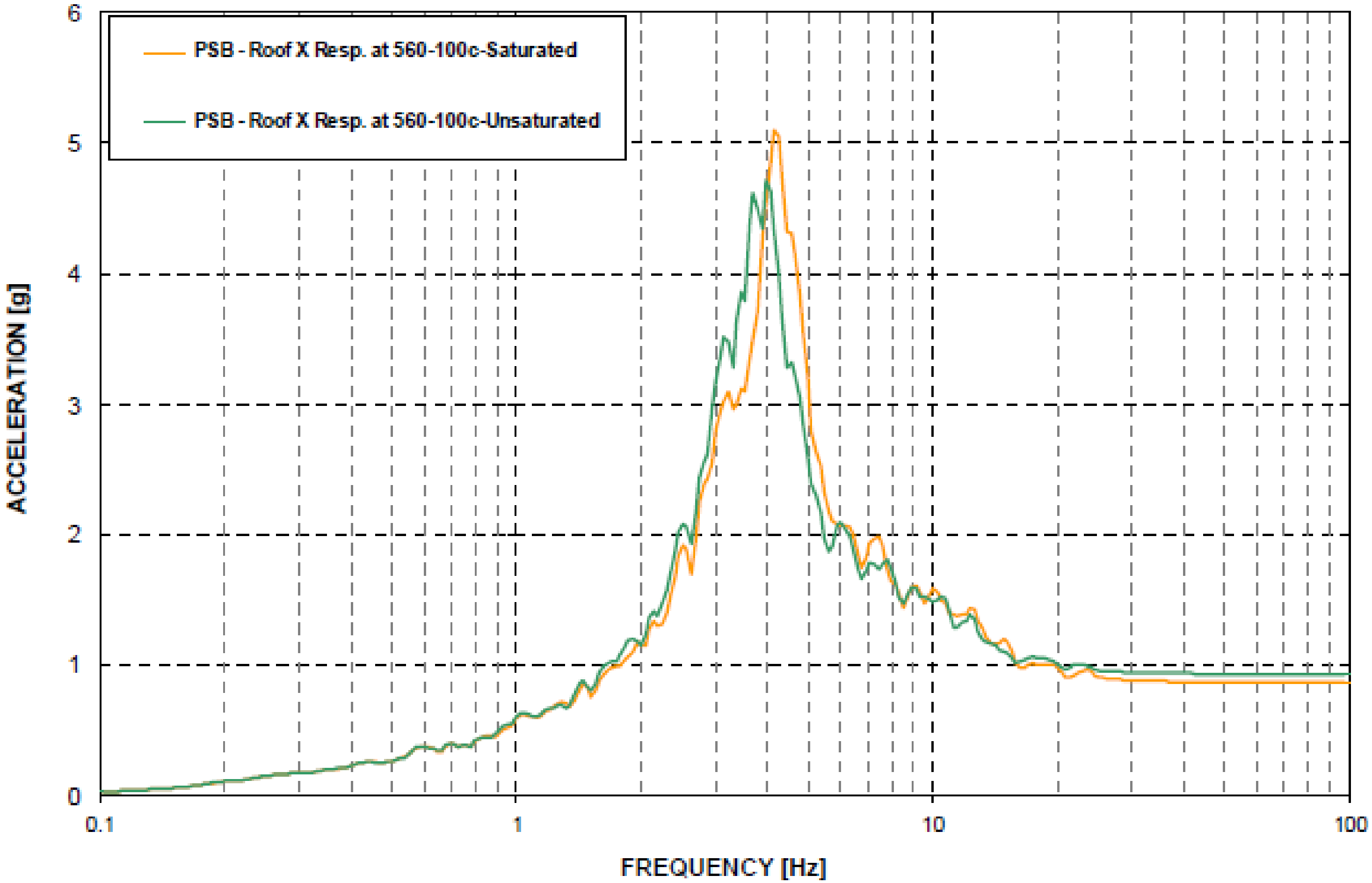
B. Effects of Ground Water Table

PS/B Roof Vertical ISRS 270-200 and 270-200D



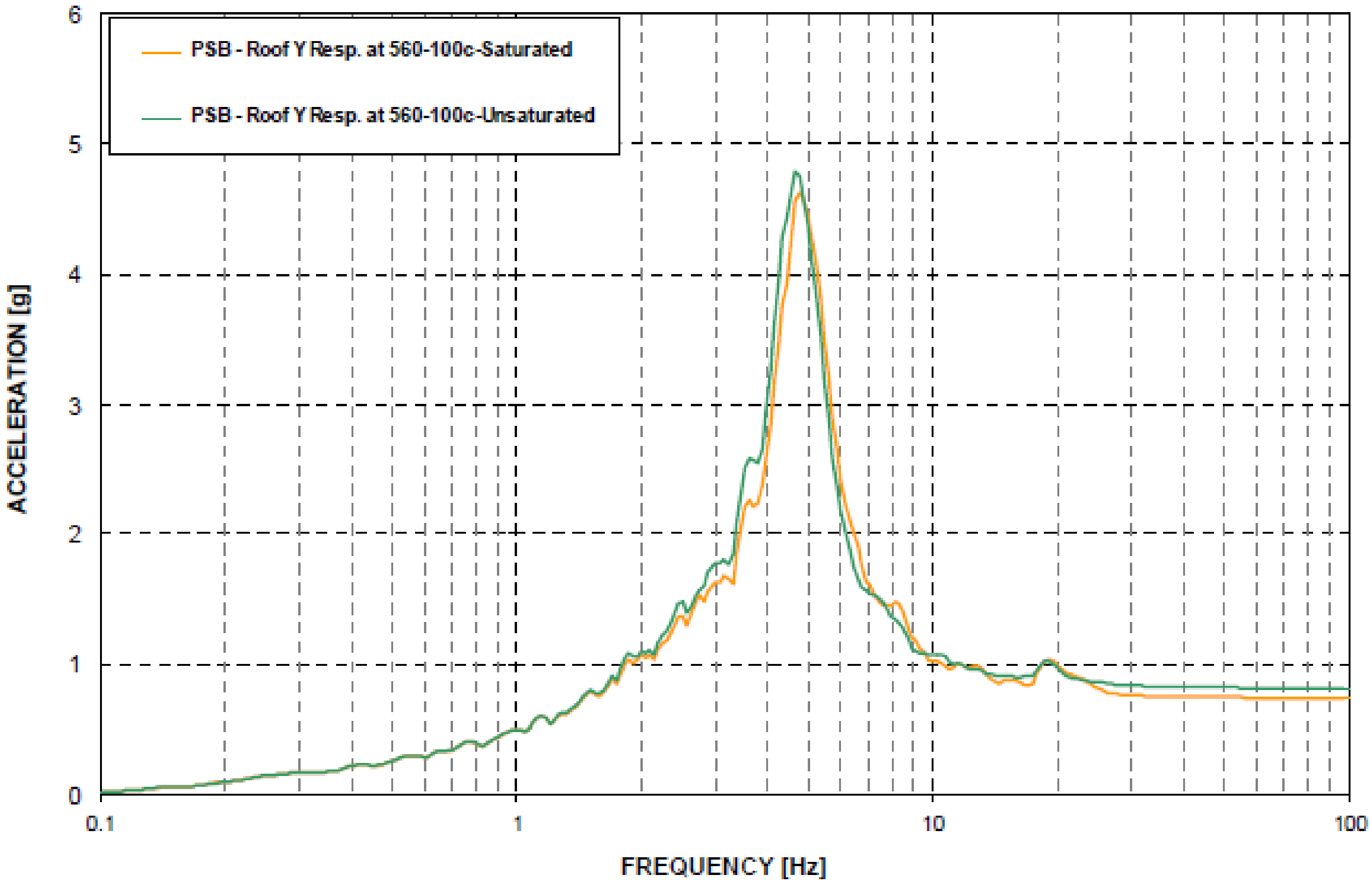
B. Effects of Ground Water Table

PS/B Roof N-S ISRS 560-100 and 560-100D



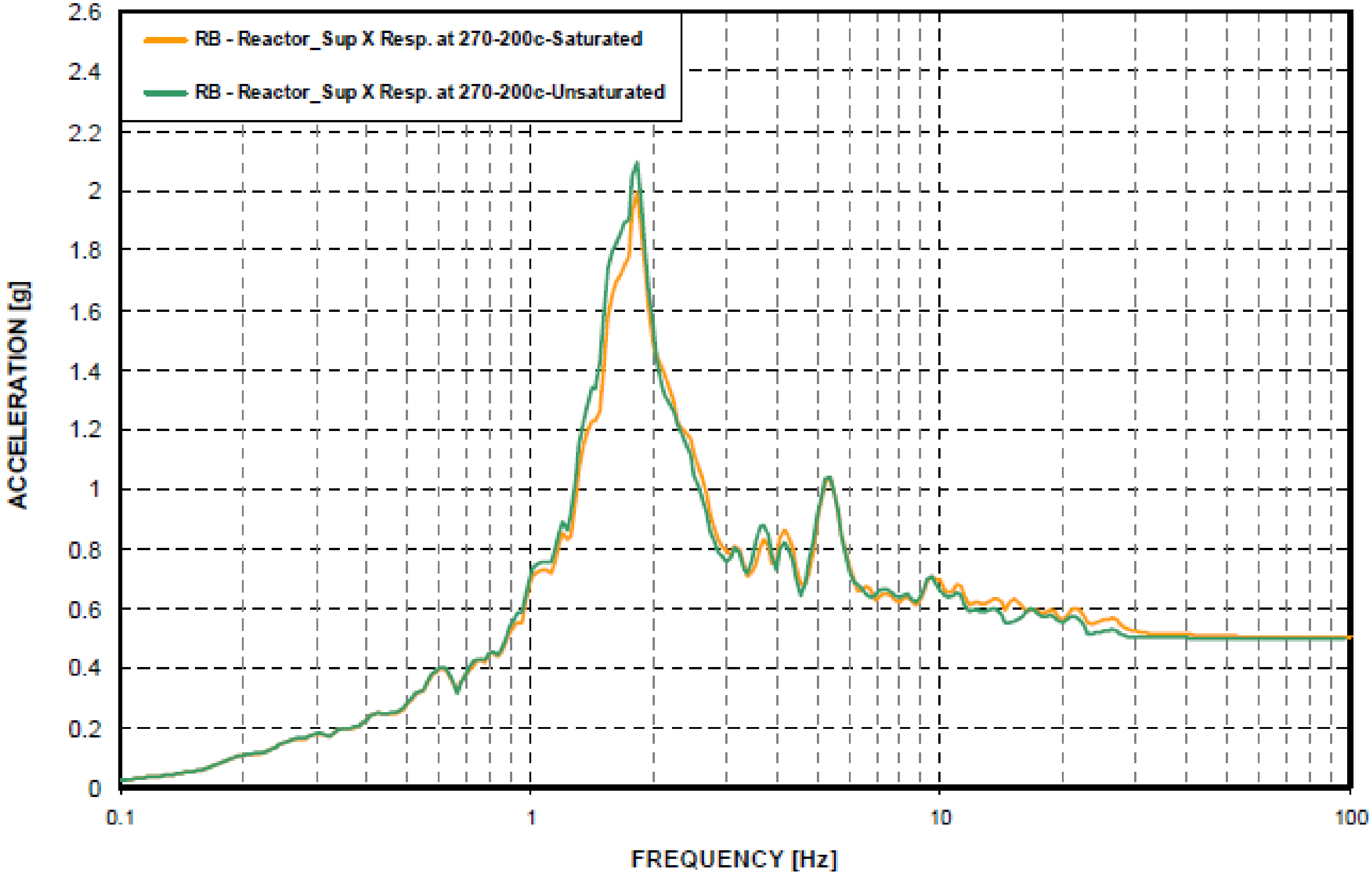
B. Effects of Ground Water Table

PS/B Roof Vertical ISRS 560-100 and 560-100D



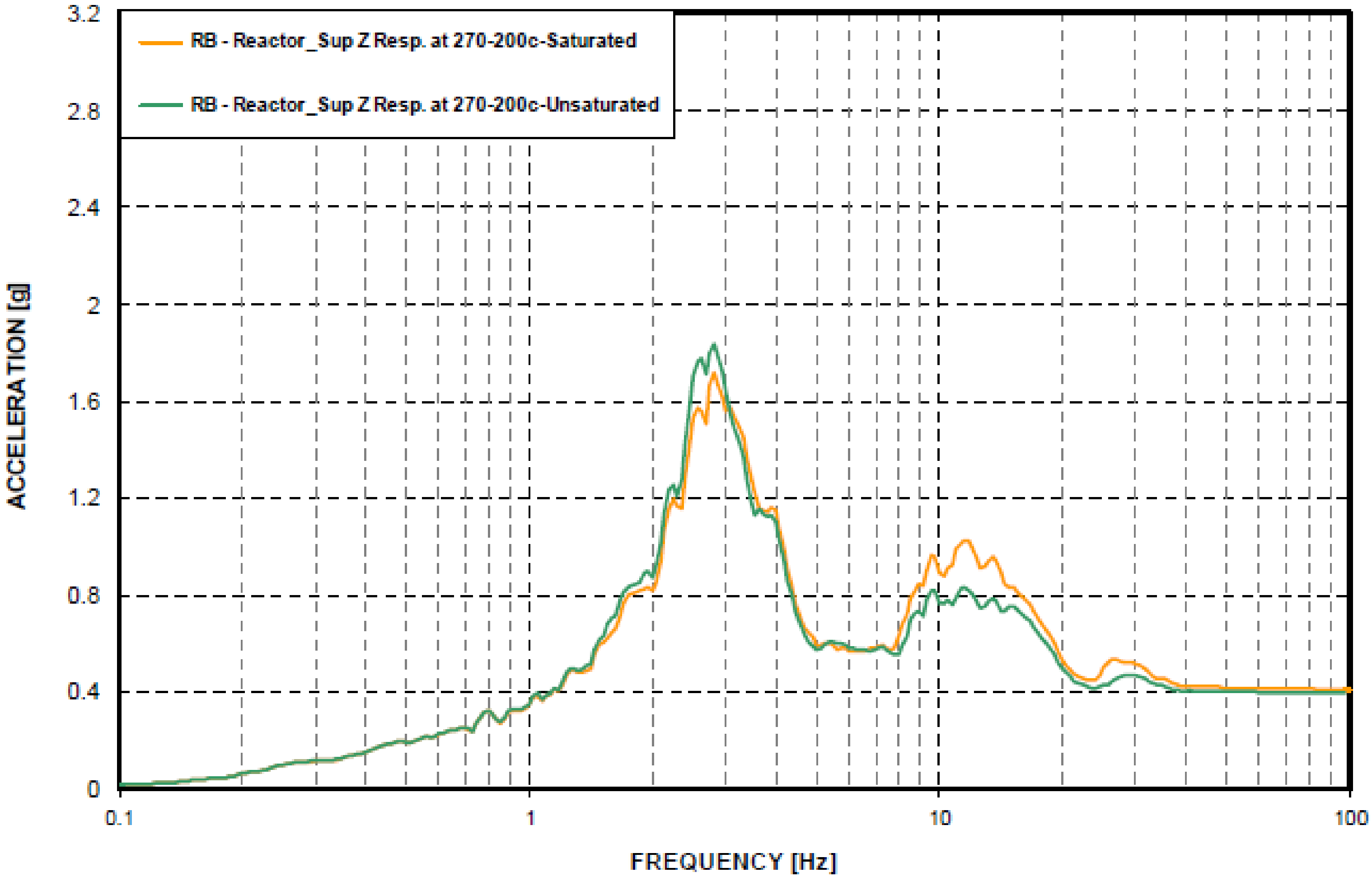
B. Effects of Ground Water Table

RV Support N-S ISRS 270-200 and 270-200D



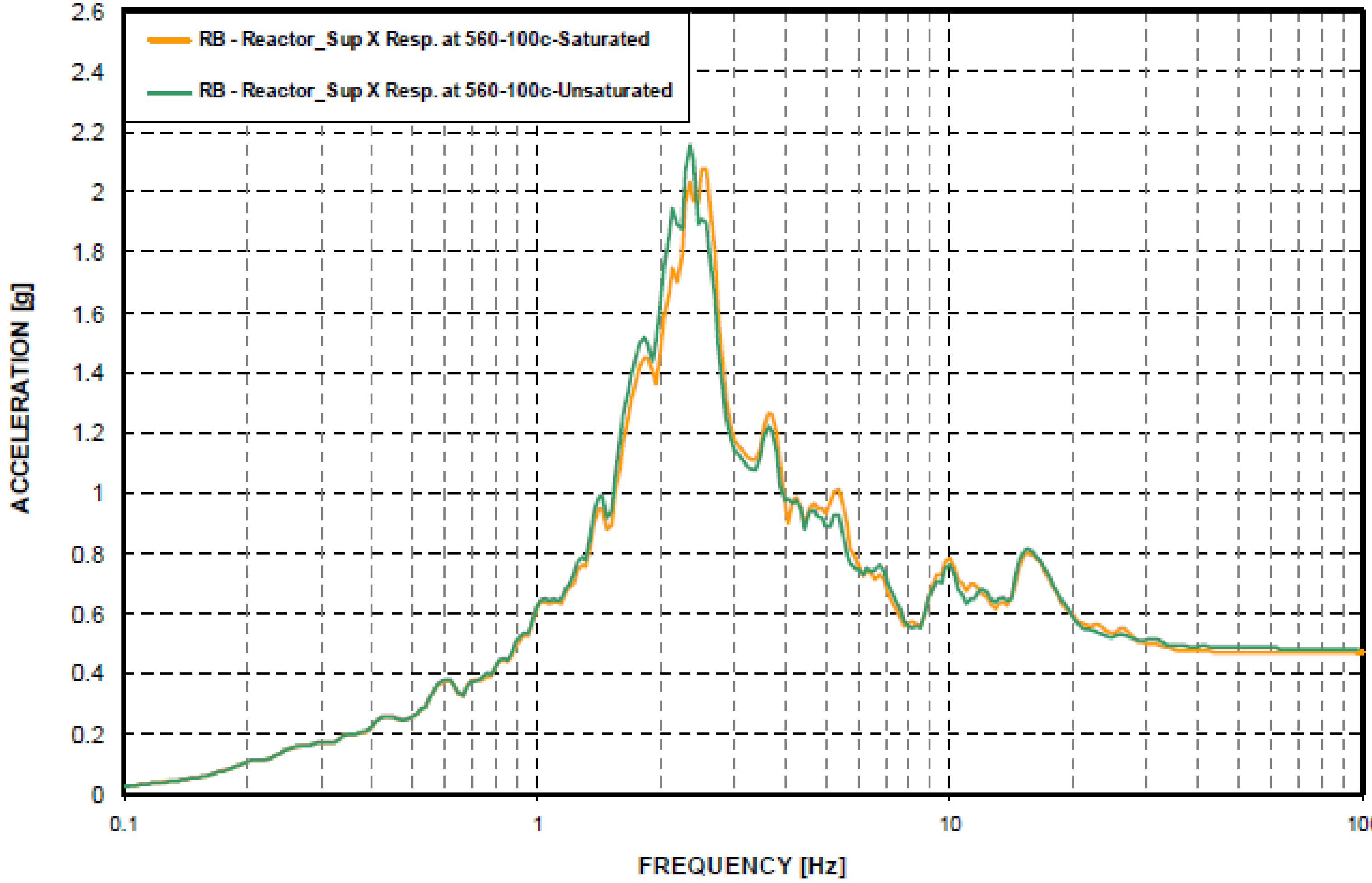
B. Effects of Ground Water Table

RV Support Vertical ISRS 270-200 and 270-200D



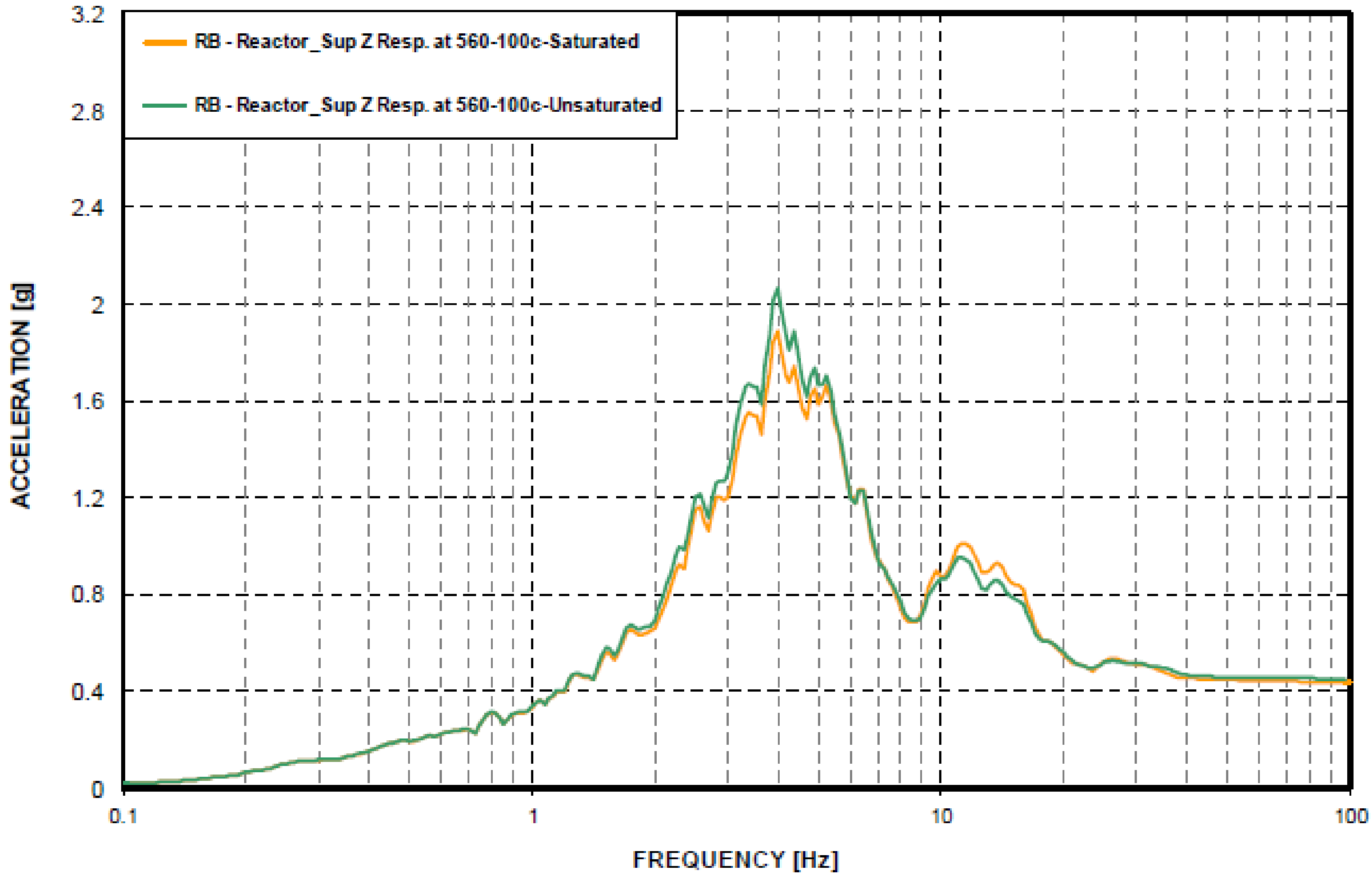
B. Effects of Ground Water Table

RV Support N-S ISRS 560-100 and 560-100D



B. Effects of Ground Water Table

RV Support Vertical ISRS 560-100 and 560-100D



B. Effects of Ground Water Table

3. Conclusion

- Lower water table elevations can slightly lower the peak frequencies and slightly amplify the magnitude of the peak response

- The frequency shifts and amplitude changes do not have a significant impact on the US-APWR standard plant design

- DCD COL Item 3.7(25) requires the applicant to perform a site-specific SSI analysis, thereby evaluating the effects of ground water on a site-specific basis

US-APWR

MUAP-11002

Overview of Turbine Building Technical Report

November 7, 2011

Mitsubishi Heavy Industries, Ltd.

Contents

- **Report Introduction**
- **Report Revisions:**
  - **Inputs**
  - **Methodology**
  - **Structure Modeling**
  - **Results**

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Report Introduction

- Report Documents Soil-Structure Interaction (SSI) and Stability Analysis of the Turbine Island (TI)
- Report Addresses
  - Turbine Building (T/B)
  - Electrical Room
- Initial Issue of MUAP-11002 Revision 0 Submitted in January 2011
- Revision 1 Incorporates All Responses to RAIs 766-5819 and 767-5821

Report Revisions - Inputs

- **Included All Six Site Profiles Consistent with MUAP-10001 (R4)**

- **Updated to Nahanni Seed Time History Consistent with MUAP-10001 (R4)**

Report Revisions - Methodology

- **Revised Cut-off Frequency**
  - **Increased to 50 Hz for fixed base validation**
  - **Increased to 50 Hz for SSI analyses of the six site profiles**
- **Revised Fixed Base Validation Analysis Using ANSYS**
- **Added Passing Frequency/Mesh Size Analysis**
- **Added Cut-off Frequency Sensitivity Analysis**

Report Revisions - Methodology

- Revised Sliding and Overturning analysis of T/B and Electrical Room Structures Using SSI Results

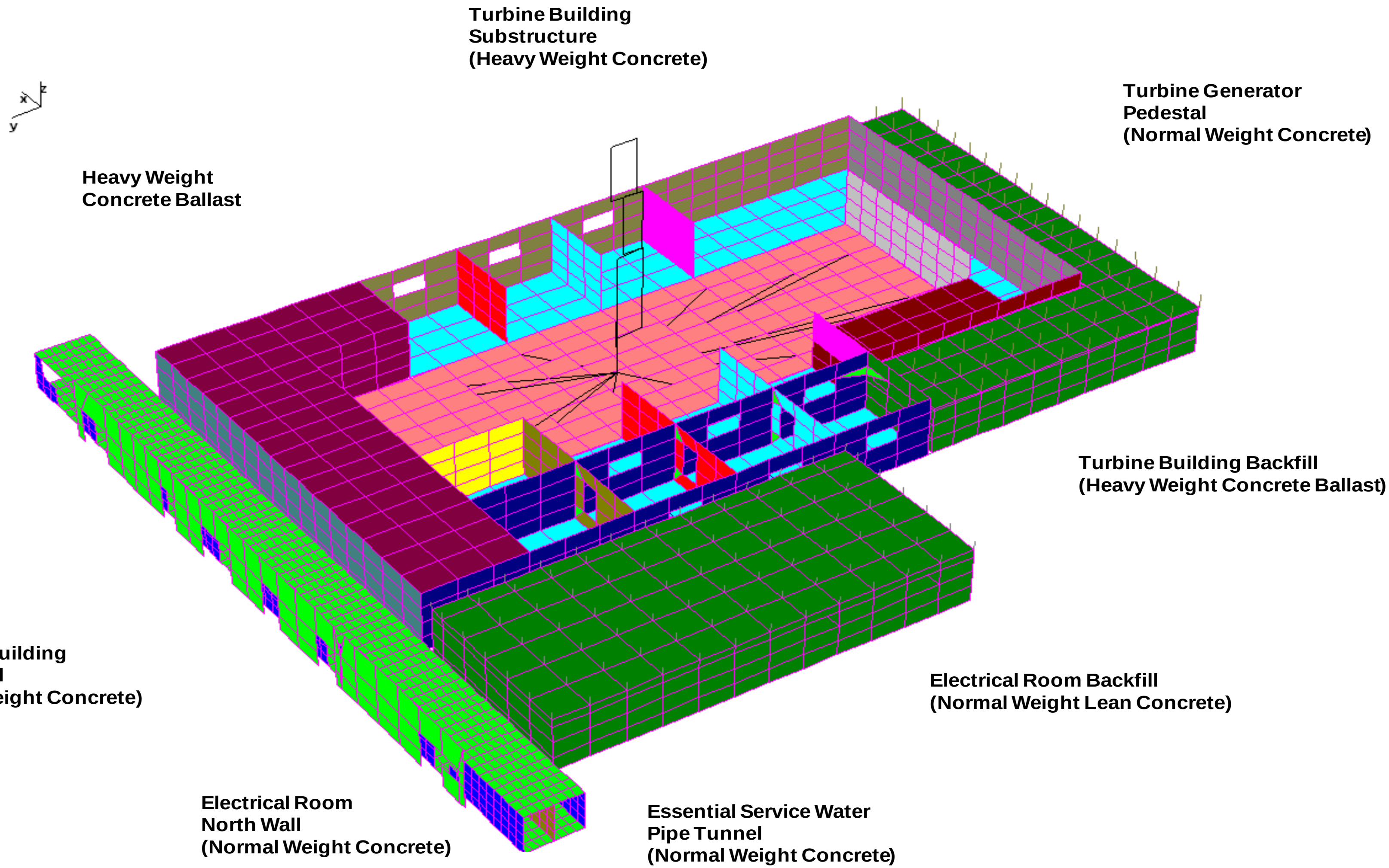
- Removed Gap Evaluation Between TI and Nuclear Island (NI)
  - Gap Evaluation to be Provided in MUAP-11011 Revision 1

- Added Gap Evaluation Between T/B and Electrical Room

Report Revisions – Structure Modeling

- **Height of T/B Updated in Accordance with DCD Revision 3**
- **Incorporated Lumped Mass Stick Model of Turbine Generator Pedestal**
- **Updated T/B and Electrical Room FE model for the Effects of Cracked Concrete in Accordance with MUAP-10001 (R4)**
- **Updated FE Model to Incorporate Additional Concrete Ballast and Heavy Weight Concrete**

View of TI Substructure



Report Revisions – Results

- **ACS SASSI Model Validation (Fixed Base)**
  - **Validation based on 21 nodes**
  - **Results compared for all three directions**
  - **ACS SASSI Model compared to fine and coarse mesh ANSYS models up to 50 Hz**
  - **Acceleration transfer function, displacement time history and response spectra plots presented for 5 nodes**

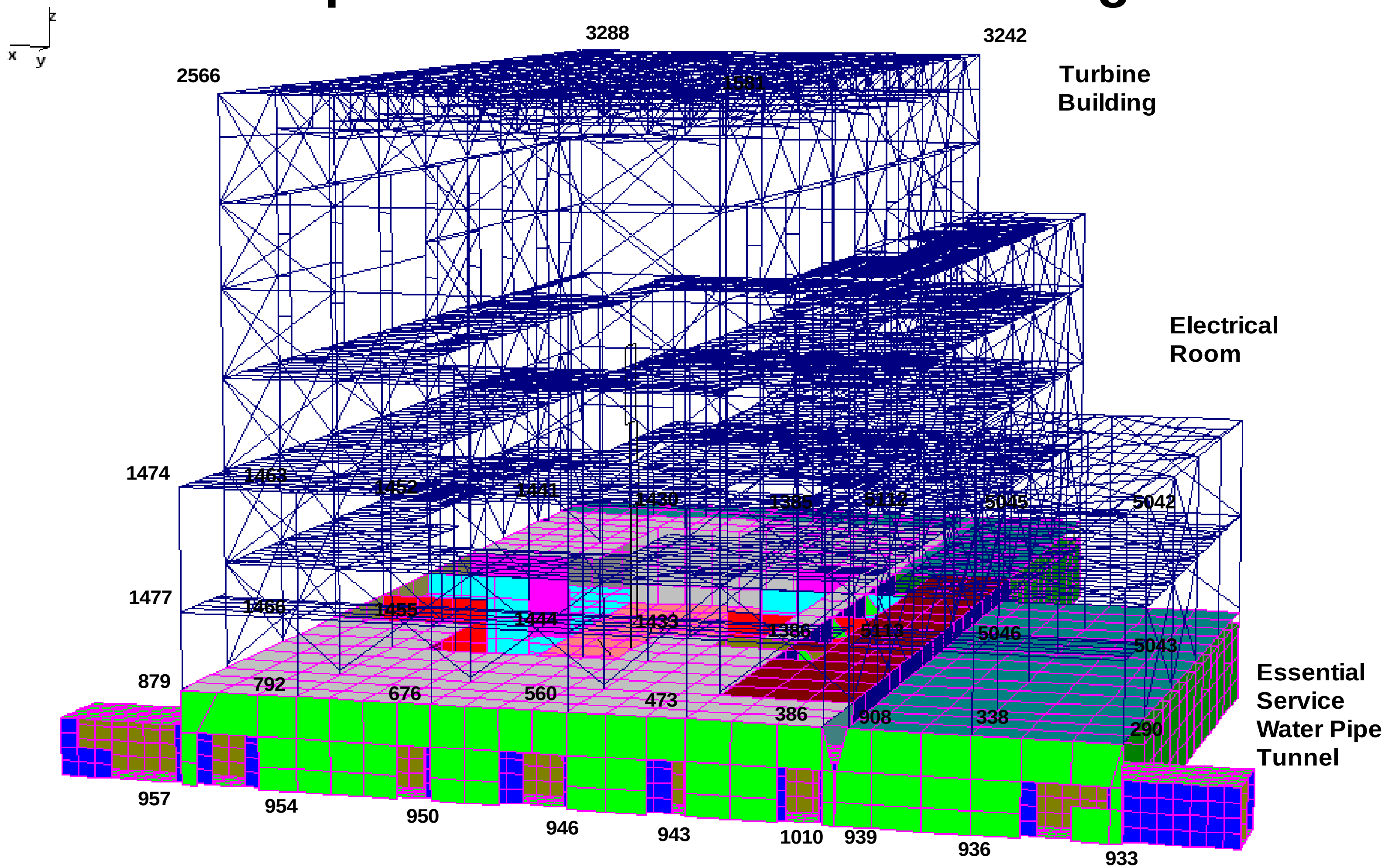
Report Revisions – Results

➢SSI Results

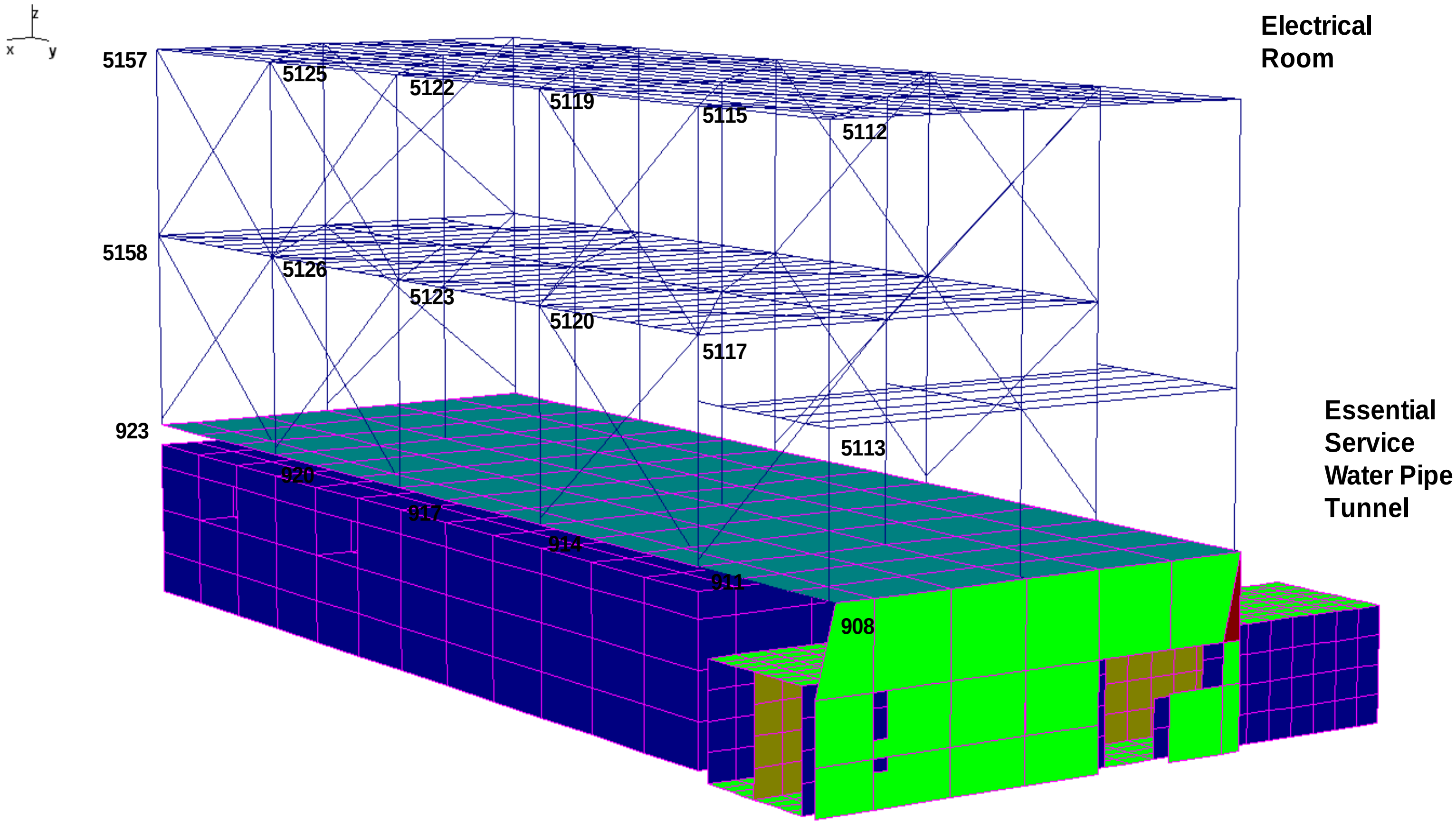
- ➢ Passing Frequency Evaluation based on Mesh Size
- ➢ Analyses Using 18Hz and 50Hz Cut-off Frequencies for Mesh Size Justification
- ➢ Displacement results for 75 nodes for X (East-West) and Y (North-South) directions
- ➢ Acceleration transfer function plots for all 75 nodes reviewed, 5 nodes presented in X and Y directions
- ➢ In general, relative displacements have increased compared to the Revision 0 report

Report Revisions – Results

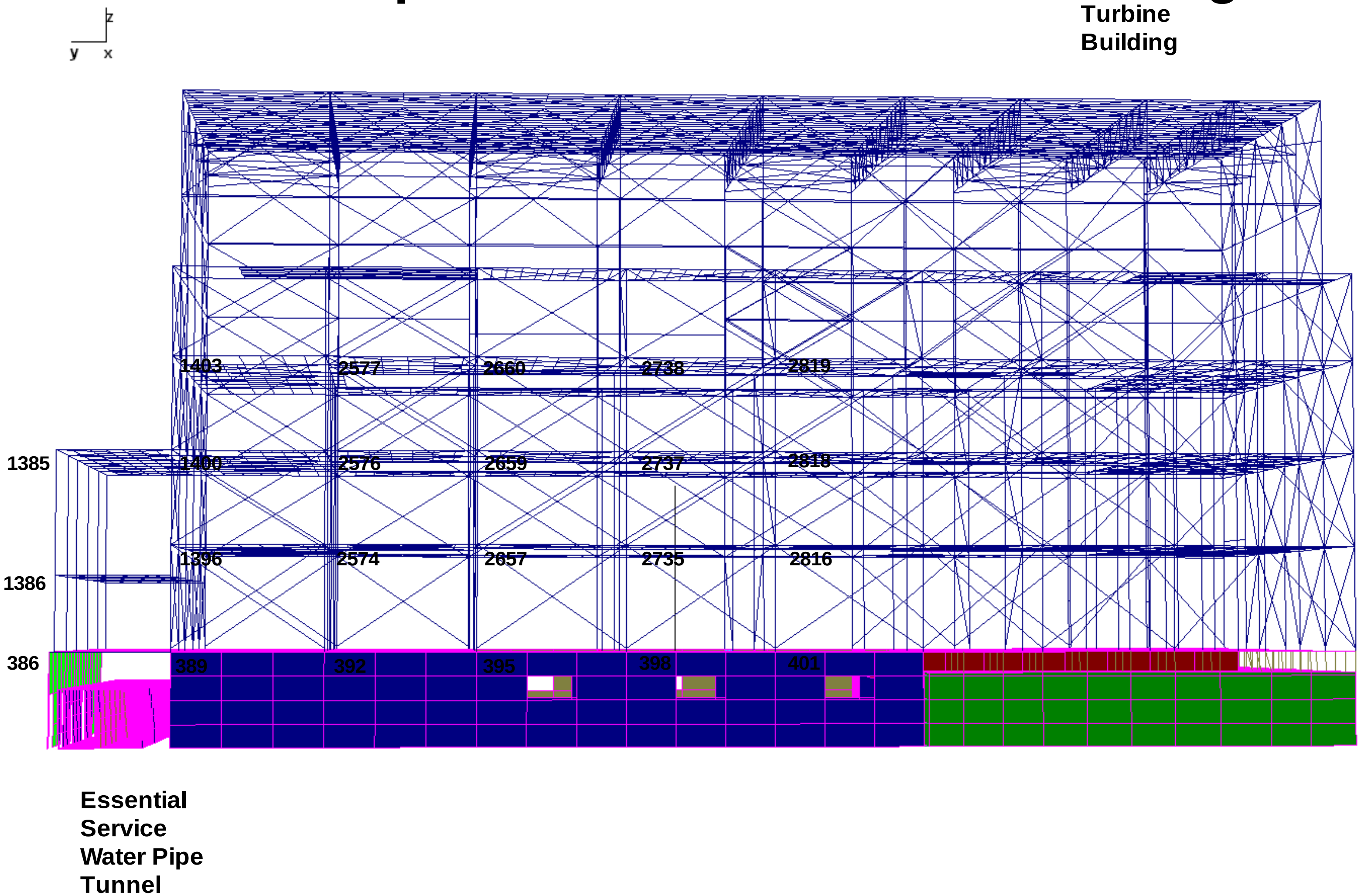
SSI Displacement Nodes – TI Looking South



SSI Displacement Nodes – Electrical Room Looking Southwest



SSI Displacement Nodes – T/B Looking East



Report Revisions – Results

- **T/B and Electrical Room Stability Evaluation (Sliding and Overturning)**
  - **Time Step Analysis Based on SSI Results**
  - **Static Friction Coefficient = 0.7 Based on:**
    - 35 degree friction angle between concrete and subgrade
    - Intentionally Roughened Concrete to Concrete Surface

Report Revisions – Results

- **Gap Evaluation**
  - **TI and Nuclear Island**
    - Not evaluated
    - To be evaluated in MUAP-11011
  - **T/B and Electrical Room**
    - Evaluated using maximum relative to free-field displacement, sliding displacement, and tilt due to settlement
  - **T/B and Turbine Generator Pedestal**
    - Not Evaluated in MUAP-11002
    - Site-Specific

US-APWR

MUAP-11001 & MUAP-11011

Description of Contents in Future Submittal

November 7, 2011

Mitsubishi Heavy Industries, Ltd.

MUAP-11001 Auxiliary Building Analysis

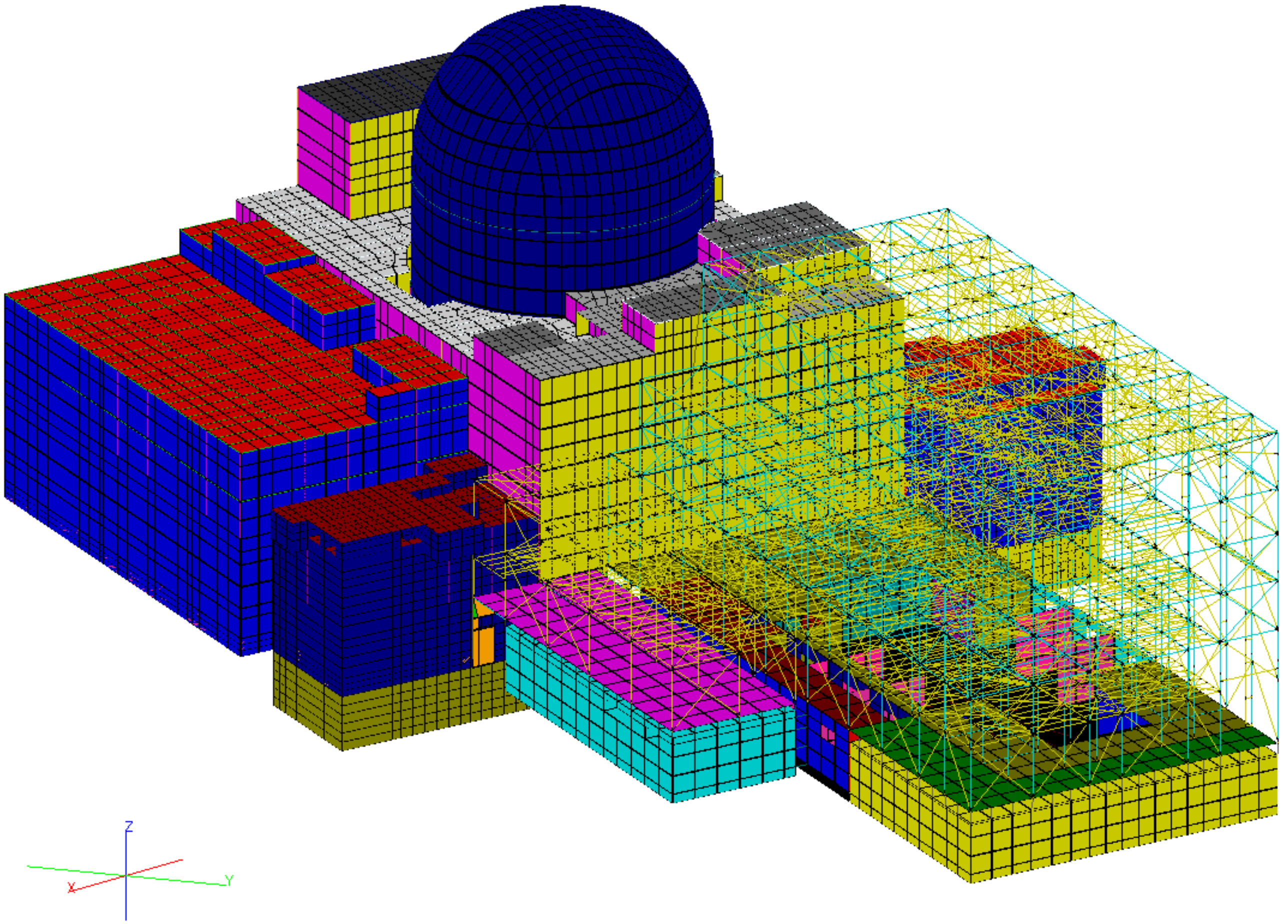
- **Dynamic analysis complete using FEM**
- **Basic design assessment complete**
- **Stability (sliding and overturning) assessment acceptable**
- **Contact ratio and bearing pressure are challenges**
- **Anticipated solution will involve introduction of a ballast structure which is currently being finalized**
- **Auxiliary Building with ballast will be modeled as part of SSI and SSSI analyses**
- **SSI results will require revision to the Dynamic Analysis and Basic Design Assessment when complete**
- **Revised MUAP-11001 is planned to be submitted in January 2012 (to be finalized)**

MUAP-11011 SSSI Analysis

- **Approach had been progressive in nature considering select building combinations using LMSM representations where possible (MUAP-11011 Revision 0)**
- **MUAP-11011 approach is being revised to consider:**
  - ✓ FEM for each building
  - ✓ All standard plant buildings in a single analytical model
  - ✓ Modeling of building features including:
    - R/B complex with shear keys
    - PS/B with ballast
    - T/B with ballast
    - A/B with ballast
  - ✓ Results of the gap assessment
- **Results may impact design ISRS for Seismic Category I Structures**
- **MUAP-11011 containing the results with this approach is planned to be submitted in January 2012 (to be finalized)**

MUAP-11011 SSSI Analysis

- **Combined Dynamic FE Model for SSSI analysis of US-APWR Standard Plant**
  - ✓ Model to be updated to include A/B and T/B ballast



US-APWR

RAI Disposition Plan for Technical Reports

November 7, 2011

Mitsubishi Heavy Industries, Ltd.

Historical RAIs

- **Issue Statement**

  Previously submitted RAIs response may no longer be valid due to changes in methodologies and new results

- **Current Status / Resolution Proposal**

  All previous Section 3.7 and 3.8 RAIs have been reviewed and grouped. New responses are being prepared as appropriate

- **Deliverables**

  List of historical RAIs with categorization and updated responses will be provided in November 2011

  Note: The division between historical and new occurred June 30, with the previous submittal of Technical Reports

Historical RAI Categorization

A. No material effect

A1. The RAI question is no longer applicable because its subject is no longer used by the DCD or its design documents (e.g., lumped-mass-stick-model usage for PCCV static analysis)

A2. DCD changes do not alter the response or associated mark-ups, or they alter a response that was superseded by a subsequent response, or they alter mark-ups in a manner unrelated to the response

B. Editorial changes only

C. Material effect – Response revision required

Historical RAI Current Status

Distribution of Historical RAIs

		No update required			Will be updated	
	total	**a1**	**a2**	**b**	**28-Nov**	**Deferred***
3.7.1	19	1	8		8	2
3.7.2	66	21	11		32	2
3.7.3	19		18		1	
3.7.4	4		4			
3.8.1	26	2	15		9	
3.8.3	35		26		9	
3.8.4	49	3	36		8	2
3.8.5	41	5	12	2	16	6
Total	259	32	128	2	83	12

* Associated with MUAP-11001 or MUAP-11011

New RAIs

- **Issue Statement**

  Multiple RAI questions have been received.   The responses were not complete prior to submittal of the Technical Reports

- **Current Status / Resolution Proposal**

  The questions were reviewed and the SMEs incorporated information into the Technical Reports

- **Deliverables**

  Most responses do not require additional analyses and will be provided by the end of November

Status of New RAIs

DCD Section	RAI Set	Number of Questions	Response Plan	Associated TR
3.7.1	798-5876	3 (of 4)	Answered in UAP-HF-11296 dated 9/7/11	
		1 (of 4)	End of November	MUAP-11007 (Studies)
	821-5984	1	End of November	MUAP-10001 (Methodology)
	850-6002	13	End of November	MUAP-10001 (Methodology)
3.7.2	766-5819	27	Mid-November	MUAP-11002 (Turbine Bldg)
	776-5851	16	Following TR submittal	MUAP-11001 (Aux Bldg)
	791-5864	1	Following TR submittal	MUAP-11001 (Aux Bldg)
	800-5879	4	Mid-November	MUAP-10024 (Access Bldg)
	810-5874	5 (of 18)	Answered in UAP-HF-11324 dated 9/22/11	
		12 (of 18)	Mid-November	MUAP-10001 (Methodology)
		1 (of 18)	End of November	MUAP-10001 (Methodology)
	812-5983	1	Answered in UAP-HF-11325 dated 9/22/11	
	852-6003	9 (of 29)	End of November	MUAP-10001 (Methodology)
		20 (of 29)	**See following slides**	MUAP-10001 (Methodology)
	853-6029	8 (of 12)	**See following slides**	MUAP-11006 (LMSM)
		4 (of 12)	**See following slides**	MUAP-11006 (LMSM)
	854-6088	13	12/23/11 (60 day response)	MUAP-11007 (Studies)
	856-6094	14	Following TR submittal	MUAP-11011 (SSSI)
3.7.3	799-5877	5	Answered in UAP-HF-11297 dated 9/7/11 and UAP-HF-11347 dated 10/7/11	
3.8.1	768-5830	1	Answered in UAP-HF-11231 dated 7/25/11	
3.8.3	858-6126	20	12/23/11 (60 day response)	MUAP-10013, 18, 19, 20 (SC walls)
3.8.4	767-5821	2	Mid-November	MUAP-11002 (Turbine Bldg)
3.8.5	855-6090	4	12/23/11 (60 day response)	MUAP-11007 (studies)

Discussion of Select New RAIs

- **RAI 852-6003 (20 questions)**
  Respond in January 2012.
  The RAI questions require validation re-analyses in order to establish more consistent boundary conditions between ANSYS and SASSI models

Discussion of Select New RAIs

- **RAI 853-6029 (8 questions)**
  Respond in December 2011.
  These responses will provide additional explanation, clarification, or justification of the evaluations that were performed

- **RAI 853-6029 (4 questions)**
  Respond in January 2012.
  Questions 139, 143, 146 and 148 require additional calculations and modeling to demonstrate the LMSM accurately matches the FE model

US-APWR

Modification to Time History Input

November 7, 2011

Mitsubishi Heavy Industries, Ltd.

Contents

- Issue Statement
- Resolution
- Summary

Issue Statement

- March 2011 changes made in methodology for seismic analyses resulted in amplification of building base shear and overturning moment response due to the MUAP-10001 R3 Time History thus impacting sliding stability and soil bearing pressures
- US-APWR MUAP-10001 R3 Time Histories based on the Northridge earthquake do not provide as good a fit to the CSDRS as the Time Histories developed from the Nahanni earthquake
- MUAP-10001 Rev. 3 time history seeds are from the BAL (Mt. Baldy) recording of the January 24, 1994 Northridge Earthquake

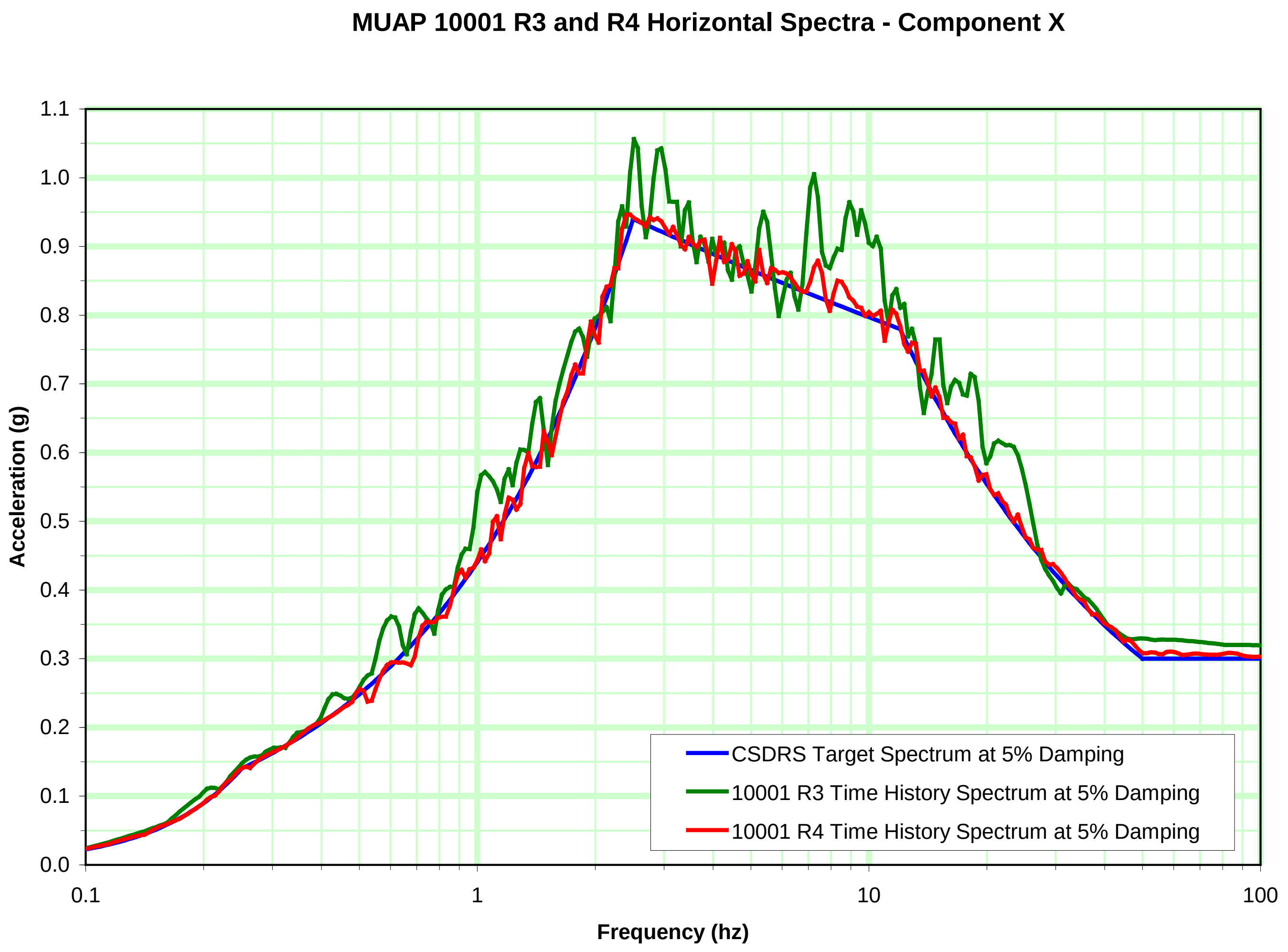
Resolution

- Replace the MUAP-10001 Rev. 3 seed records with the December 25, 1985 Nahanni Canada earthquake recorded at Site 3 (M 6.76) for MUAP-10001 Rev. 4
- Develop three time histories from these seed records to match the CSDRS in accordance with NUREG 0800, Section 3.7.1, March 2007
- Use NUREG 0800 methodology compliant with Subsection 3.7.1.II.1B, Option 1, Approach 2
- Analysis methodology is unchanged
- Nahanni Epicenter is > 600 miles from the fault line between the North American Plate and the Pacific Plate

Resolution

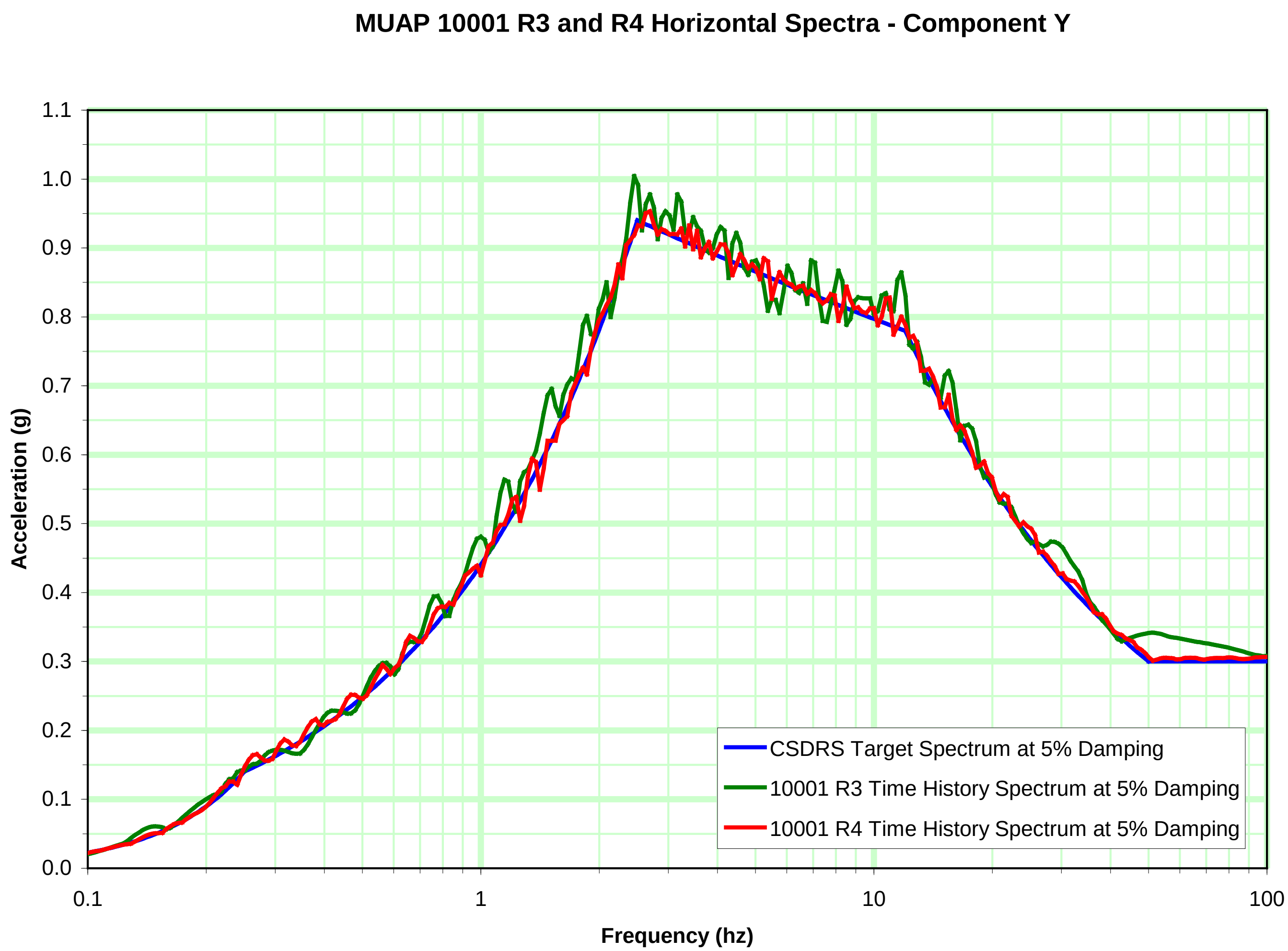
- **The revised (MUAP-10001 Rev. 4) time histories resolve challenges associated with contact area ratio and subsequent bearing pressures**
- **The revised time histories help resolve sliding stability challenges**
- **The revised time histories do not result in a reduction of critical peaks in the design basis ISRS**

Resolution

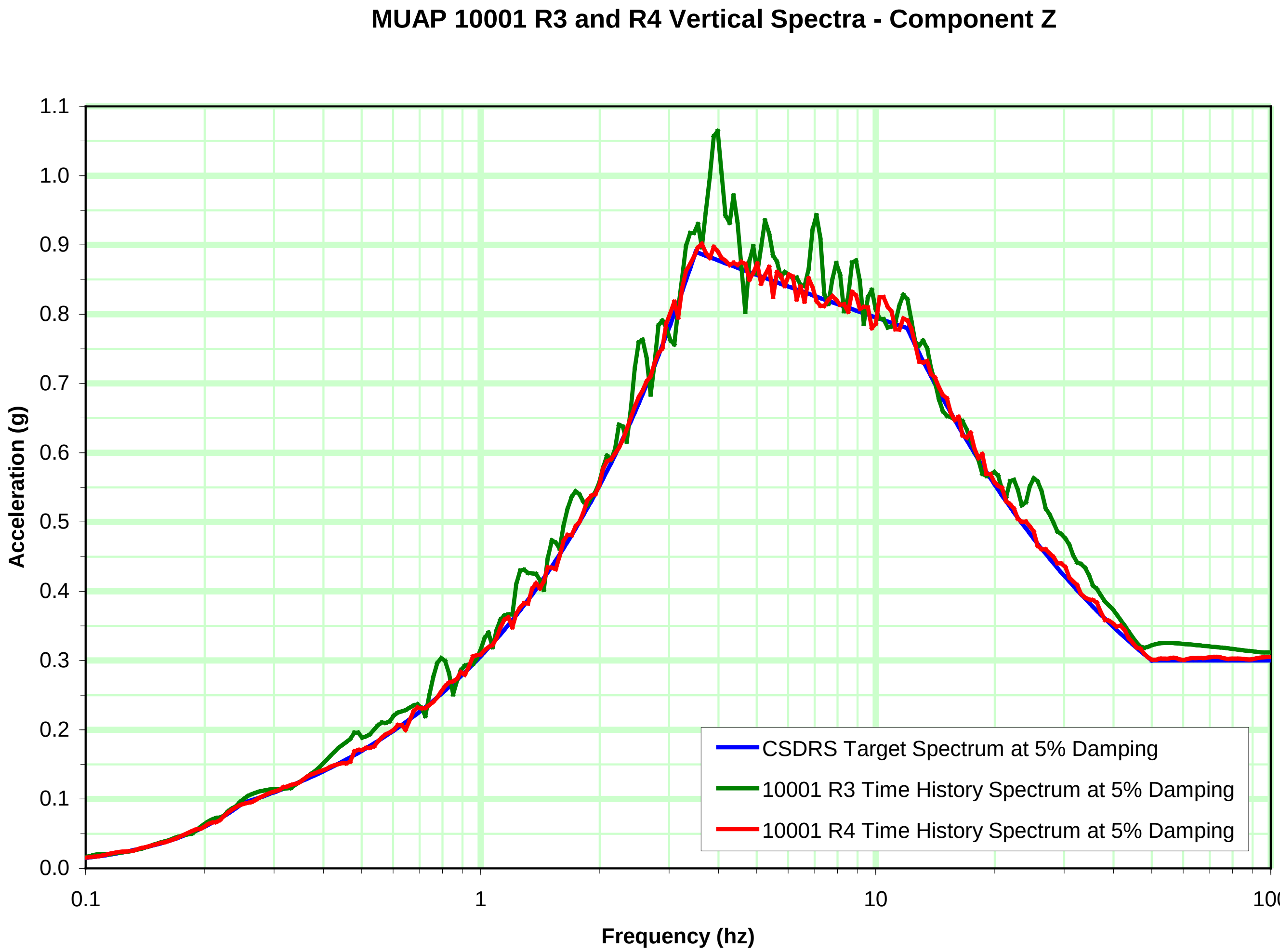


MUAP 10001 R3 and R4 Horizontal Spectra - Component X
Acceleration (g)
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.1
1
10
100
Frequency (hz)
CSDRS Target Spectrum at 5% Damping
10001 R3 Time History Spectrum at 5% Damping
10001 R4 Time History Spectrum at 5% Damping

Resolution


MUAP 10001 R3 and R4 Horizontal Spectra - Component Y
Acceleration (g)
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.1
1
10
100
Frequency (hz)
CSDRS Target Spectrum at 5% Damping
10001 R3 Time History Spectrum at 5% Damping
10001 R4 Time History Spectrum at 5% Damping

Resolution



MUAP 10001 R3 and R4 Vertical Spectra - Component Z
Acceleration (g)
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.1
1
10
100
Frequency (hz)
CSDRS Target Spectrum at 5% Damping
10001 R3 Time History Spectrum at 5% Damping
10001 R4 Time History Spectrum at 5% Damping

Resolution

NUREG 0800 3.7.1.II.1B, Option 1, Approach 2 Requirements for MUAP-10001 R4 Time Histories

Requirement	X	Y	Z
Nyquist Frequency is 100 Hz. Time step is 0.005 seconds			
Damping is 5%. Frequency scale is 0.10 to100.0 Hz			
Average all points	1.009	1.015	1.009
Total Duration (GE 20 Sec.)	20.000	20.000	20.000
Rise Time: Arias' Intensity (GE 1 Sec)	2.845	2.729	3.026
Strong Motion: Arias' 5% to 75% (GE 7 S.)	7.795	8.286	7.165
Decay Time: Arias' 75% to 100% (GE 5 S.)	9.360	8.985	9.809

Resolution

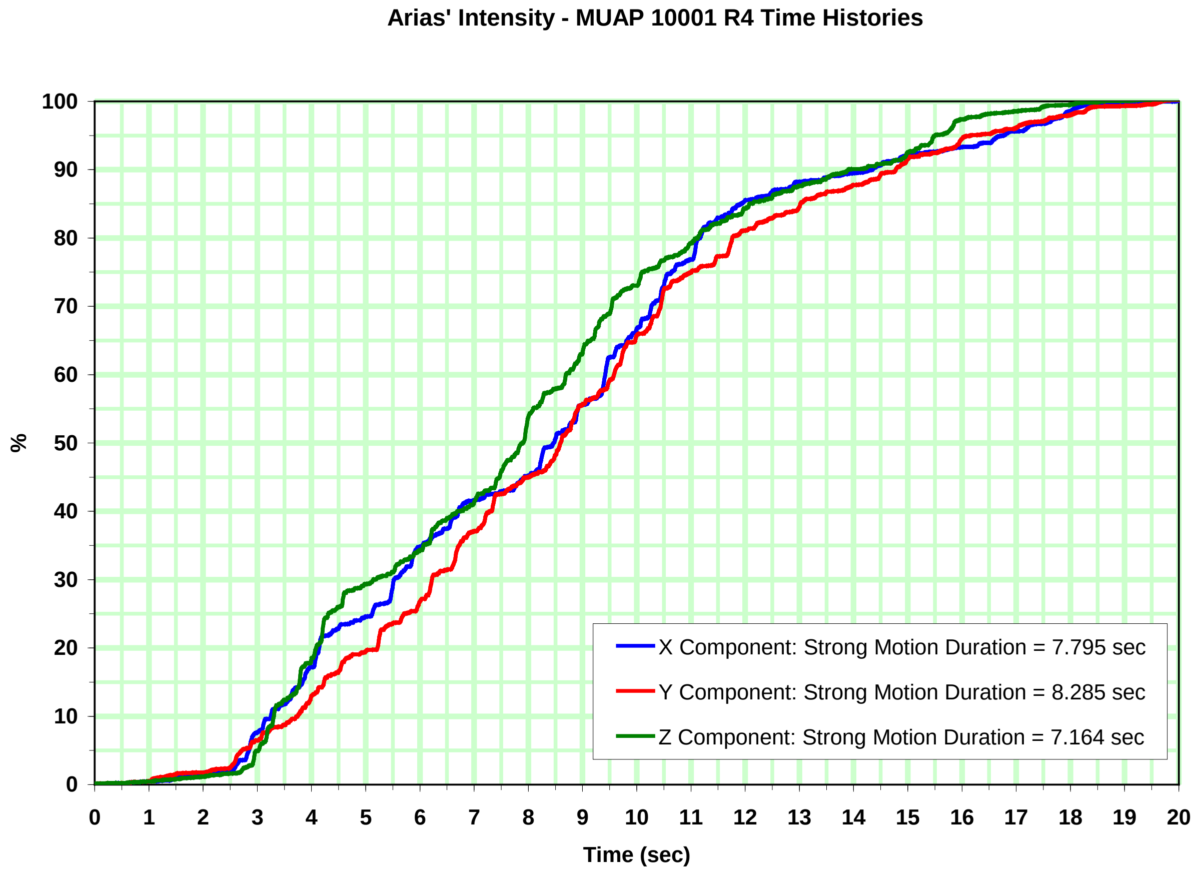
NUREG 0800 3.7.1.II.1B, Option 1, Approach 2
Requirements for MUAP-10001 R4 Time Histories

<table>
<tr><th>Requirement</th><th>X</th><th>Y</th><th>Z</th></tr>
<tr><td rowspan="3">Statistical Independence (ABS < 0.16)</td><td colspan="2">-0.0327</td><td></td></tr>
<tr><td>0.1390</td><td></td><td>0.1390</td></tr>
<tr><td></td><td colspan="2">0.1170</td></tr>
<tr><td>Number of points with acc. ratio > 1.3 (if 0 OK)</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Number of points with acc. ratio < 0.9 (if 0 OK)</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Number of windows wider than 9 points below target spectra (if 0 OK)</td><td>0</td><td>0</td><td>0</td></tr>
</table>

The MUAP-10001 R4 time histories comply with all the NUREG 0800 3.7.1.II.1B, Option 1, Approach 2 requirements

Resolution

Arias Intensity plots showing % Intensity Vs Time



Plot demonstrates reasonable intensity input with time.

Resolution

- The uplift calculation predicted unacceptably low contact area ratios for the R/B Complex using the MUAP-10001 Rev. 3 time histories and site profiles

Site Profiles	MUAP-10001 R3 Time Histories and Site Profiles		MUAP-10001 R4 Time Histories and Site Profiles	
	Bearing Pressure (ksf)	Ratio of Contact Area	Bearing Pressure (ksf)	Ratio of Contact Area
270-200	47.4	0.35	30.7	0.75
270-500	31.1	0.72	25.5	0.88
560-500	78.6	0.23	42.9	0.51
900-100	102.5	0.12	47.3	0.44
900-200	102.9	0.13	51.9	0.39
2032-100	50.5	0.24	38.2	0.58

Resolution

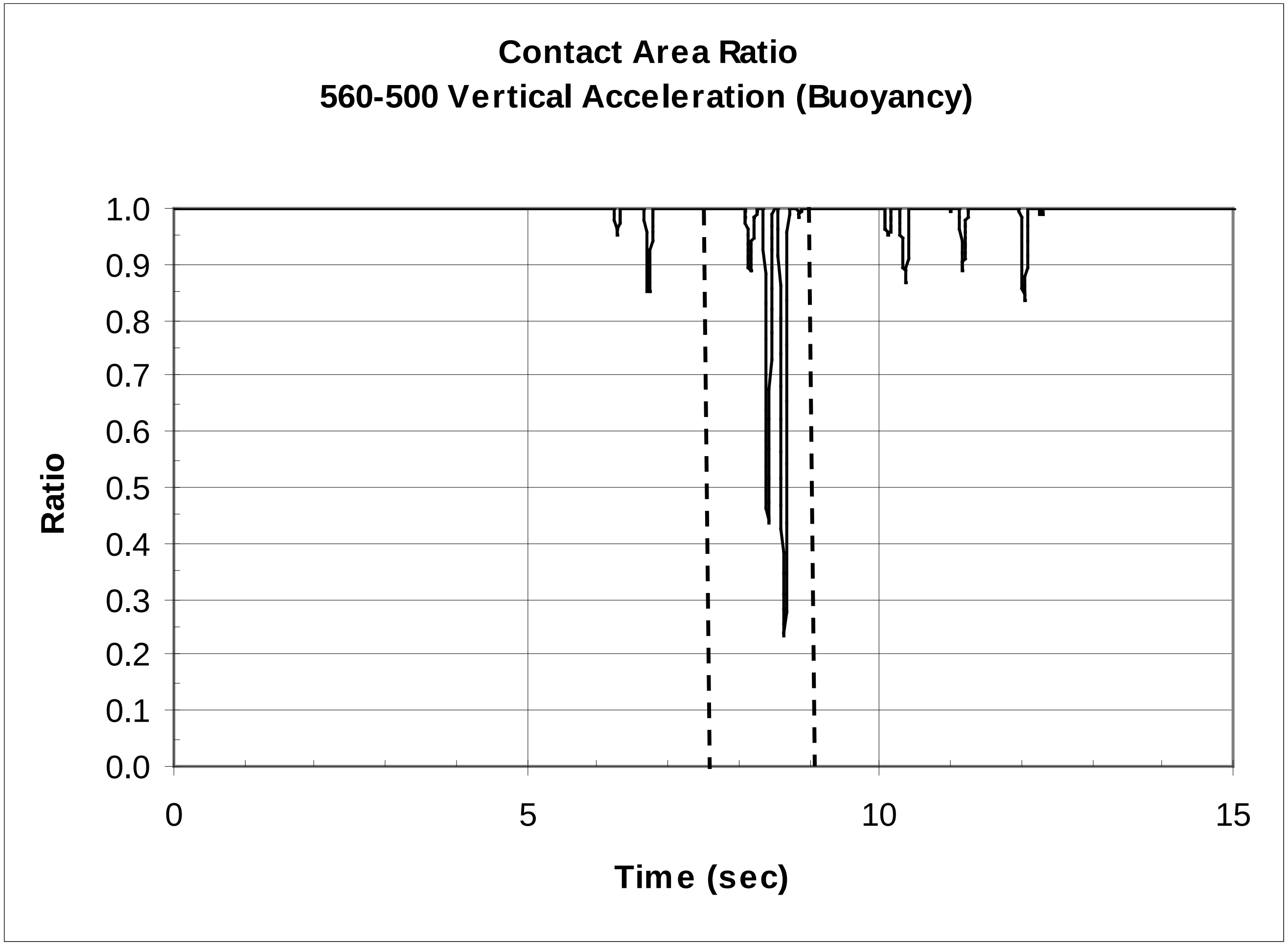
➢ **Revision of the design basis time histories produced reductions in the sliding forces (11% in X and 7% in Y), likely due to a better fit to the CSDRS**

Site Profiles	MUAP-10001 R3 Time Histories and Site Profiles		MUAP-10001 R4 Time Histories and Site Profiles	
	Seismic Fx (kip)	Seismic Fy (kip)	Seismic Fx (kip)	Seismic Fy (kip)
270-200	347,810	373,360	264,842	308,853
270-500	269,110	306,697	257,733	276,809
560-500	348,199	353,028	340,676	371,051
900-100	373,723	378,586	320,515	361,147
900-200	384,646	398,782	326,601	368,563
2032-100	352,270	355,317	294,059	341,861

Resolution

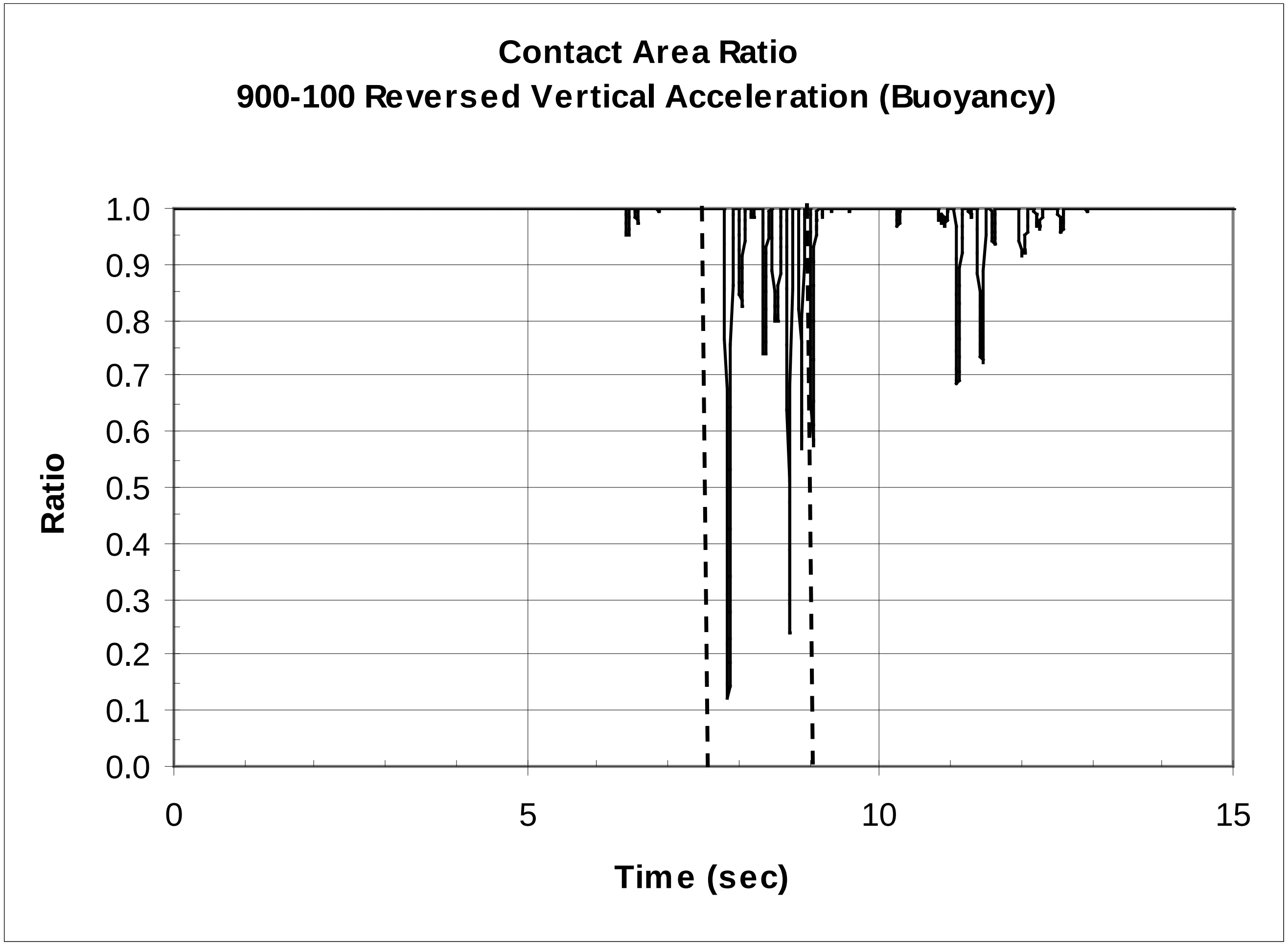
- **An examination of the uplift plots for the MUAP-10001 Rev. 3 time history indicated that the uplift occurred at approximately the same time (between 7.5 and 9 seconds) for all site profiles which led to the suspicion that the input time histories were the cause**

Resolution



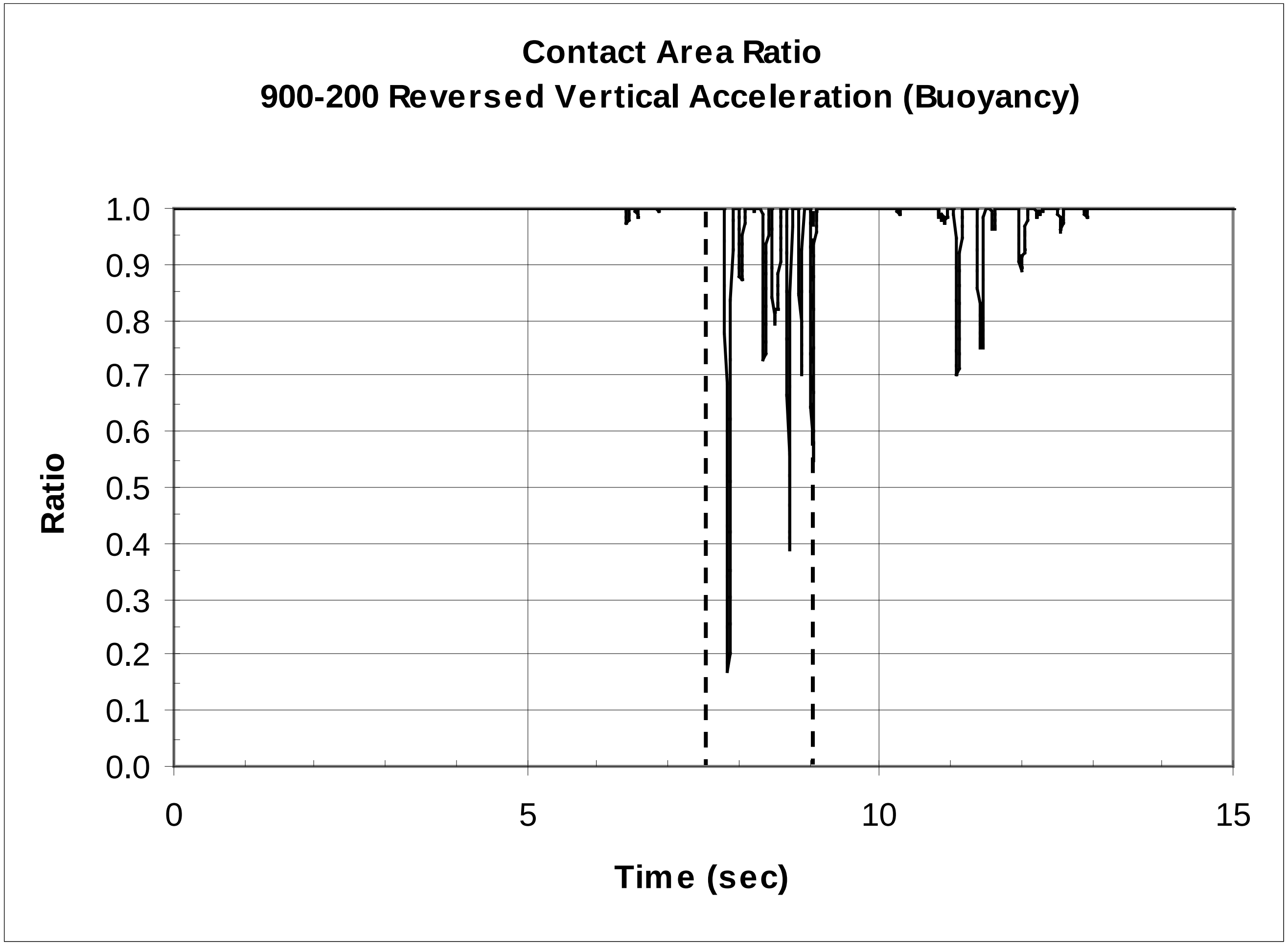
Contact Area Ratio
560-500 Vertical Acceleration (Buoyancy)
Ratio
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
5
10
15
Time (sec)

Resolution



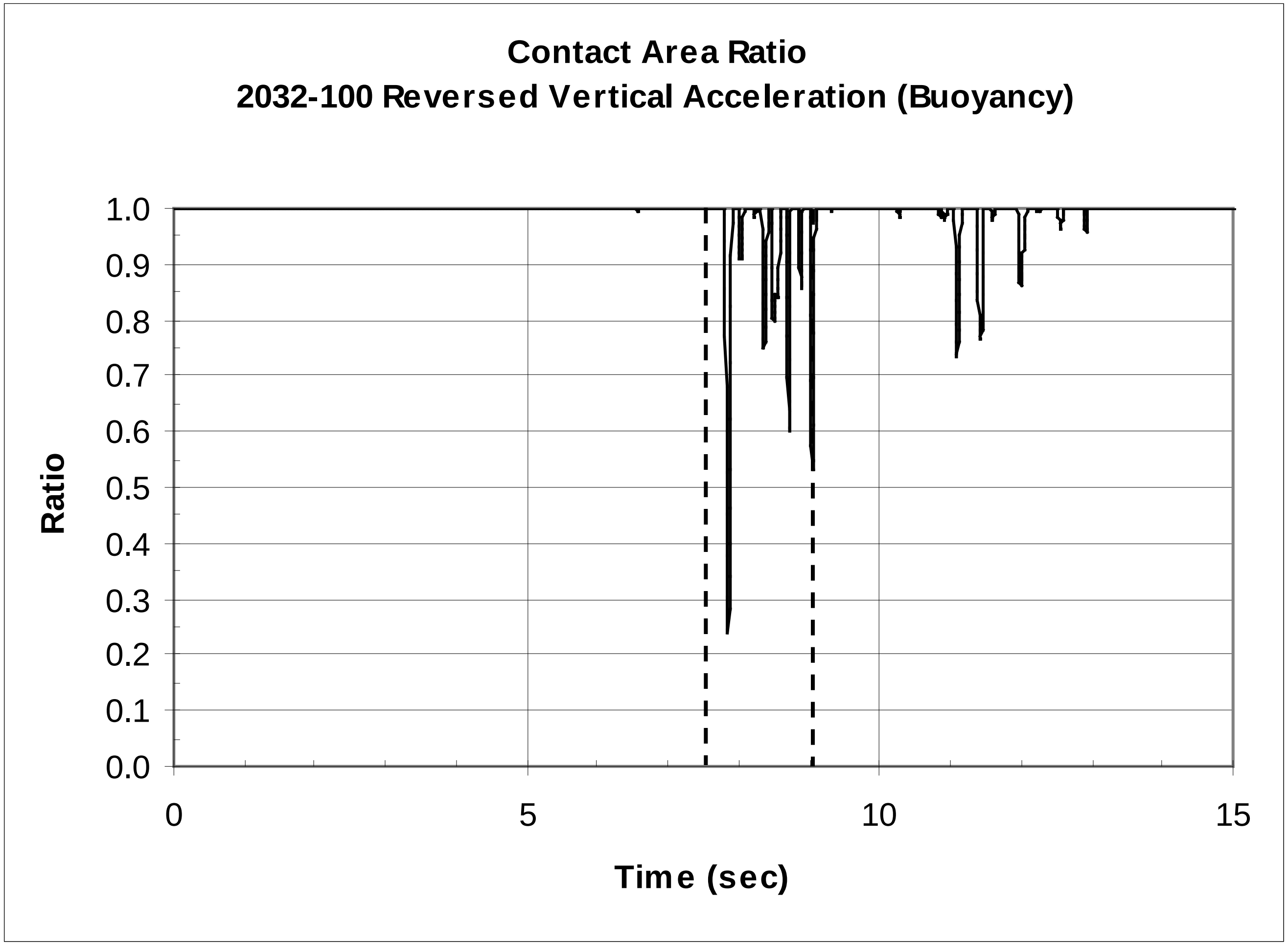
MITSUBISHI HEAVY INDUSTRIES, LTD.

Resolution



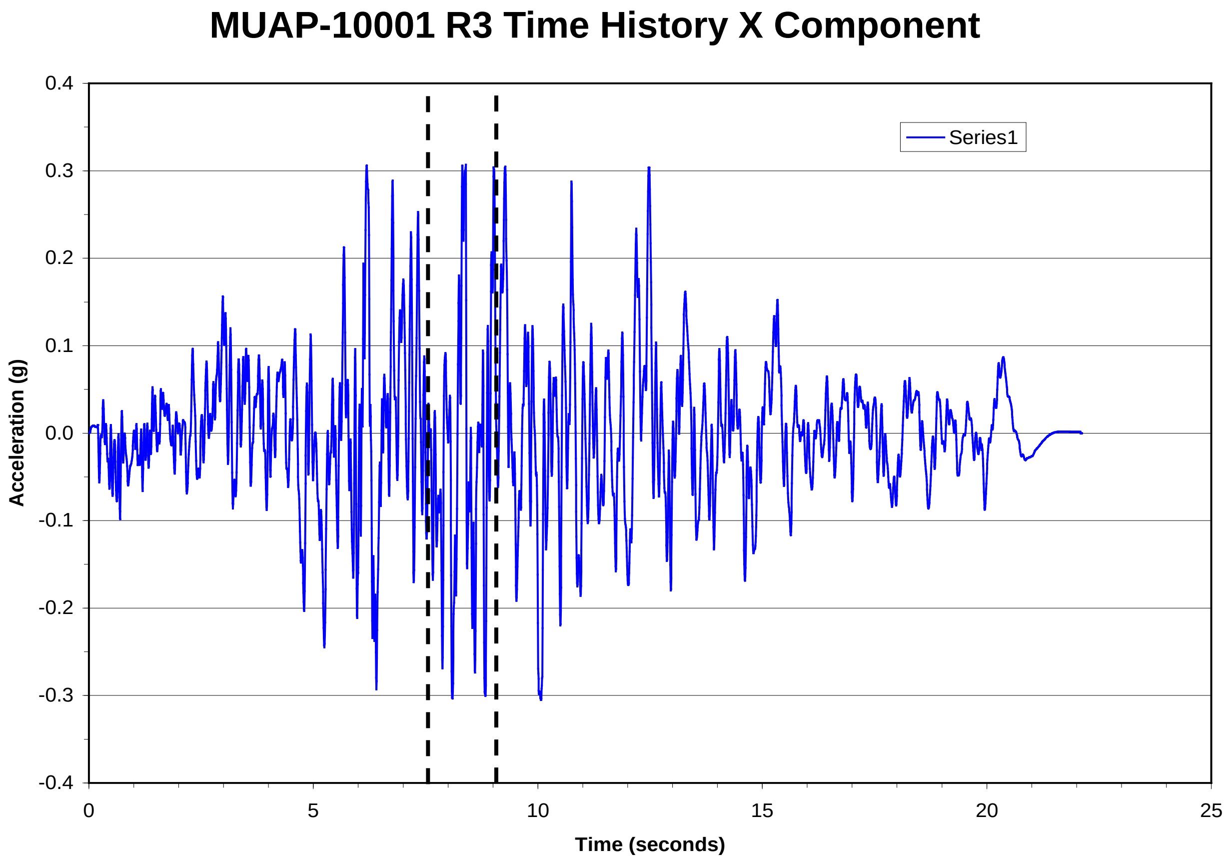
MITSUBISHI HEAVY INDUSTRIES, LTD.

Resolution

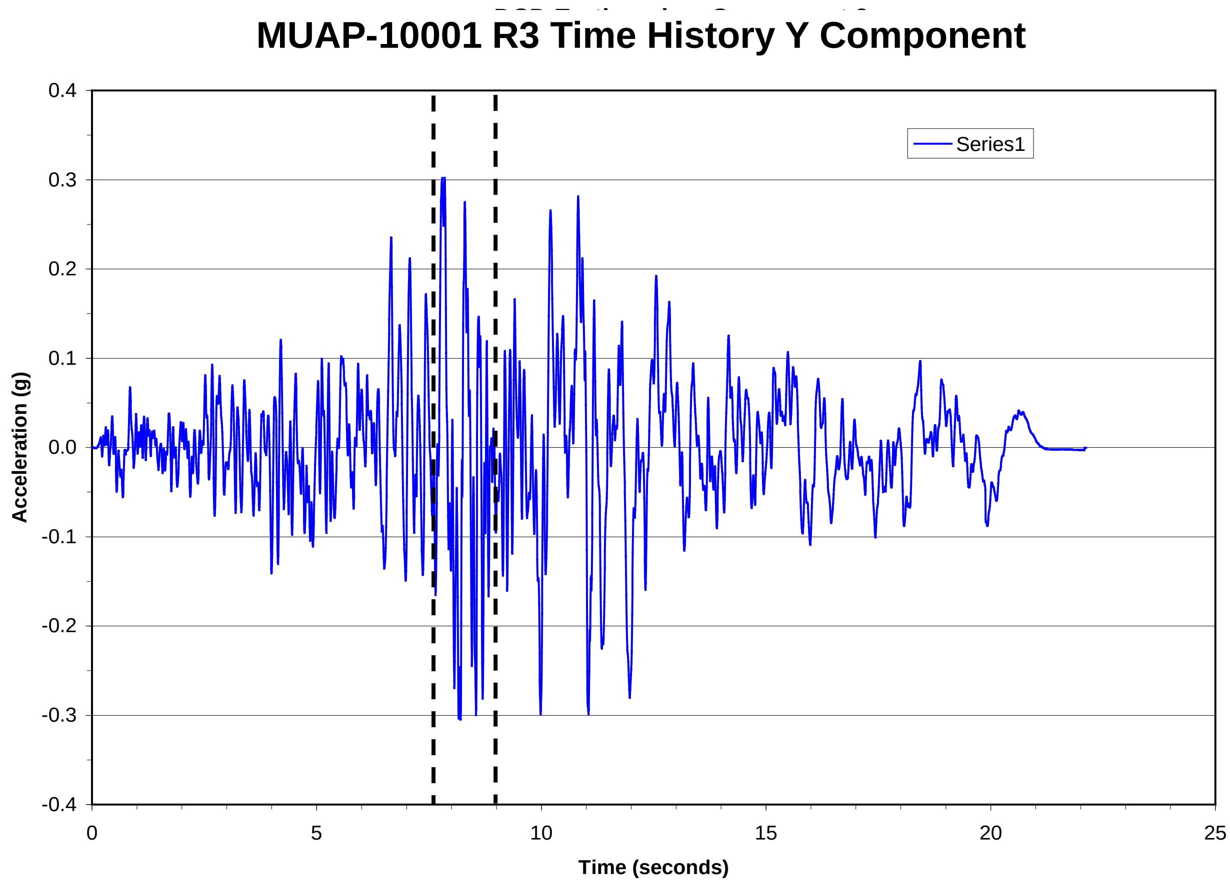

Contact Area Ratio
2032-100 Reversed Vertical Acceleration (Buoyancy)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Ratio
0
5
10
15
Time (sec)

Resolution

- This was then confirmed by examining the acceleration time history plots.



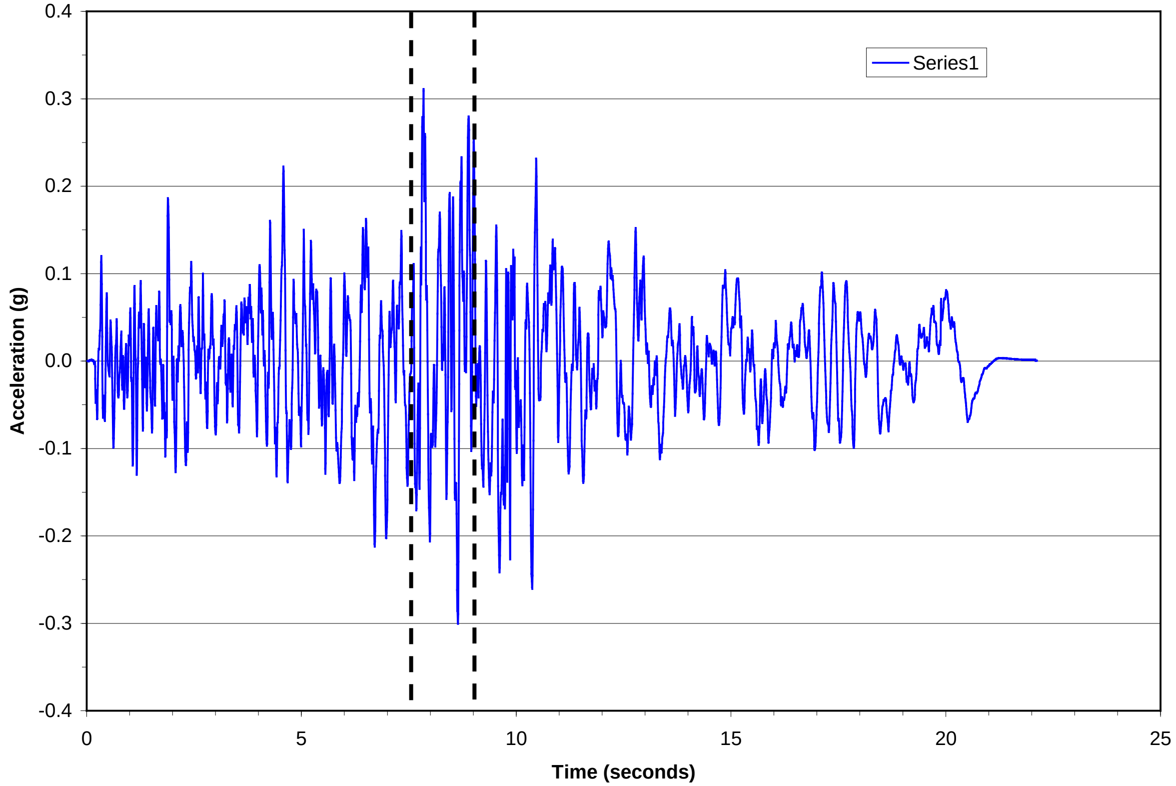
Resolution



MUAP-10001 R3 Time History Y Component
Series1
Acceleration (g)
Time (seconds)
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
0
5
10
15
20
25

Resolution

MUAP-10001 R3 Time History Z Component

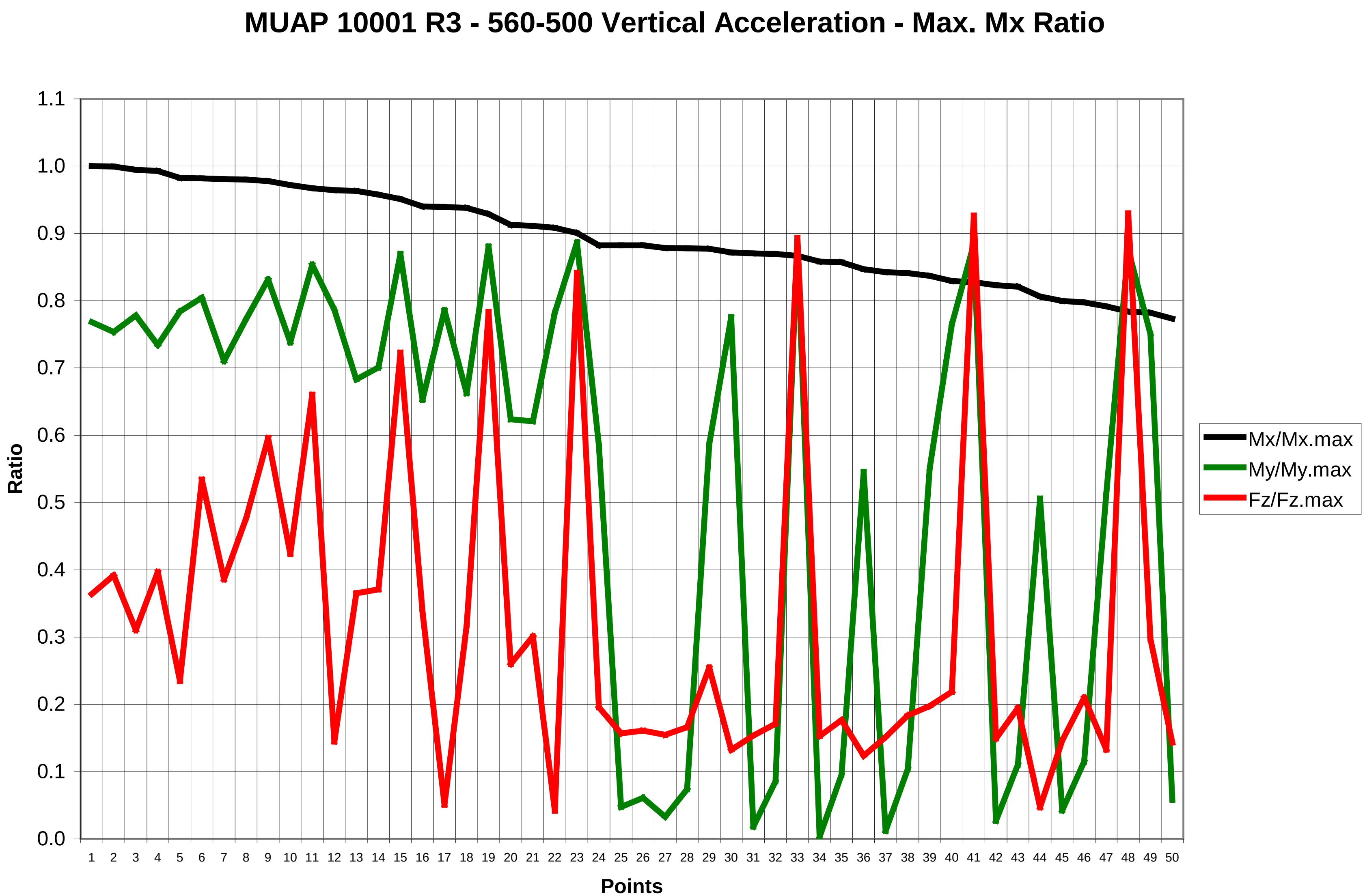


Resolution

- **This was further confirmed by examining the Mx/Mxmax and My/Mymax plots**

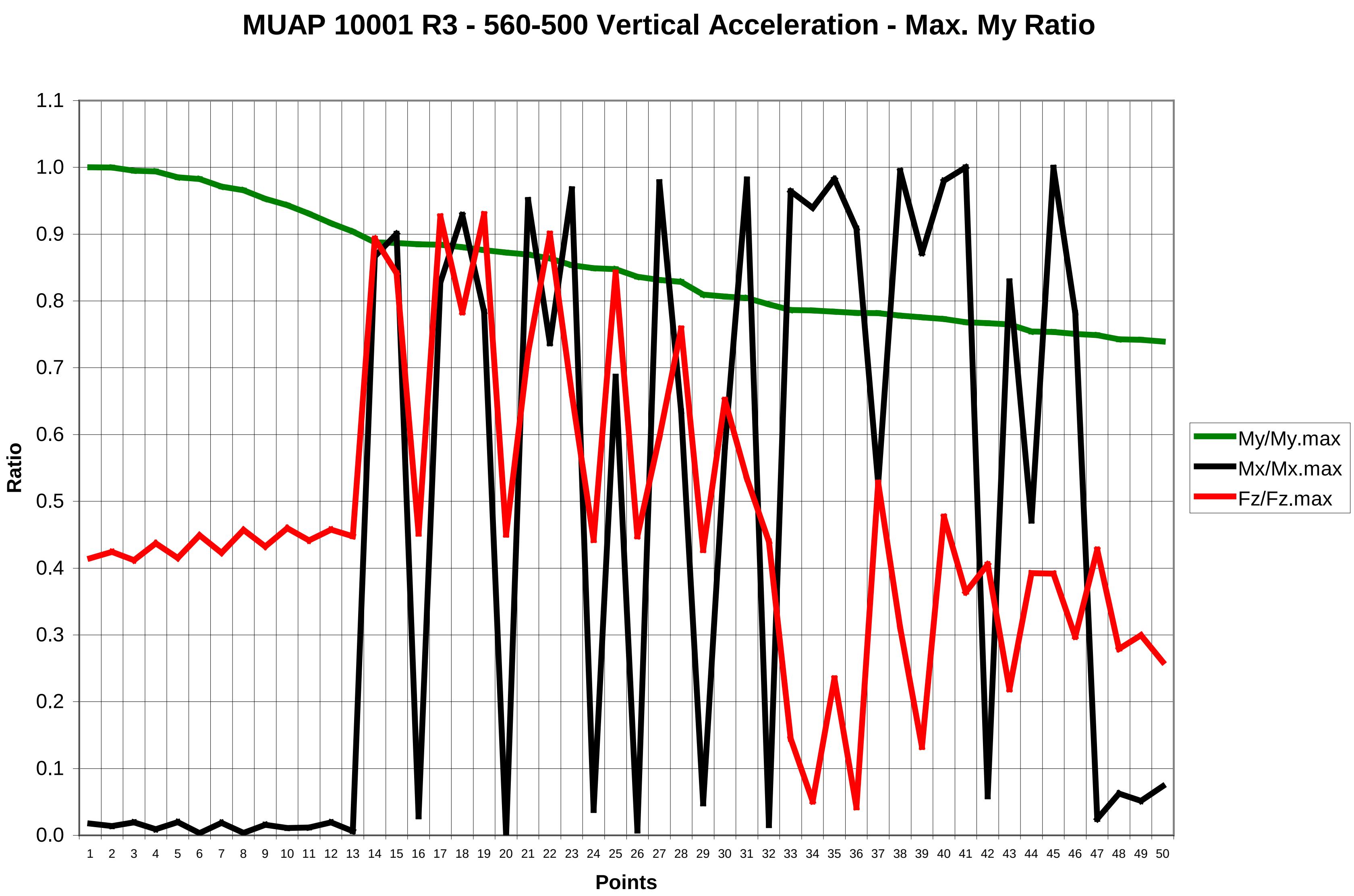
- **Plots show that the time histories do not provide approximate values that parallel the 100-40-40 rule as expected**

Resolution



MUAP 10001 R3 - 560-500 Vertical Acceleration - Max. Mx Ratio
Ratio
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50
Points
Mx/Mx.max
My/My.max
Fz/Fz.max

Resolution



MUAP 10001 R3 - 560-500 Vertical Acceleration - Max. My Ratio
Ratio
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50
Points
My/My.max
Mx/Mx.max
Fz/Fz.max

Resolution

MUAP-10001 R3 Site Profile	Mx/Mxmax (%)	My/Mymax (%)
560-500	93 90	89 89
900-100	80 79	85 90
900-200	80 80	95 91
2032-100	80 79	93 97

Resolution

- In discussion with the DCWG for an earthquake seed that is representative of the CEUS, Nahanni (M 6.76) was proposed. See “Spectral Scaling of the 1985 to 1988 Nahanni, Northwest Territories, Earthquakes”, by David M. Boore and Gail M. Atkinson, Bulletin of the Seismological Society of America, Vol. 79, No. 6, pp 1736-1761, December 1989

- 1999 Hector Mine Desert Hot Spring (M 7.10), 1989 Loma Prieta APEEL 9 Crystal Springs Res (M 6.90) and 1994 Northridge Mount Baldy Elementary School (M 6.7) were also investigated

Resolution

- To assist in the evaluation of the time histories a coefficient was developed to assess the signals. The coefficient evaluates both the correlation among the three signals and the energy they all deliver to the structure. This coefficient is computed for one (1) second portions of the time histories at each time step after one second

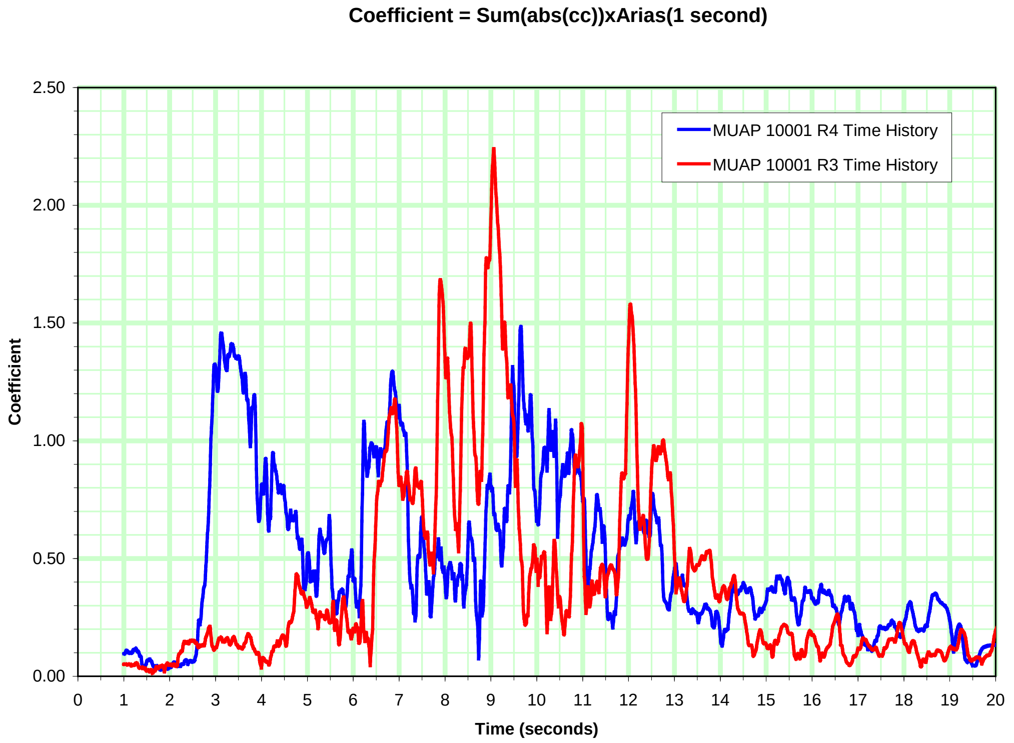
Resolution

- **Thus:**
- **At every time step it computes the correlation coefficients and the Arias Intensity (E) for the previous one (1) second interval for the entire time history.**

- **C(ti) = [ABS(CC(1,2))+ABS(CC(1,3))+ABS(CC(2,3))]X [E(1)+E(2)+E(3)] where ti is the i-th time step.**

Resolution

- It has been found that the coefficient can be used to evaluate known responses to the signals
- MUAP-10001 Rev. 3 signal shows three peaks between 7.5 and 9 seconds



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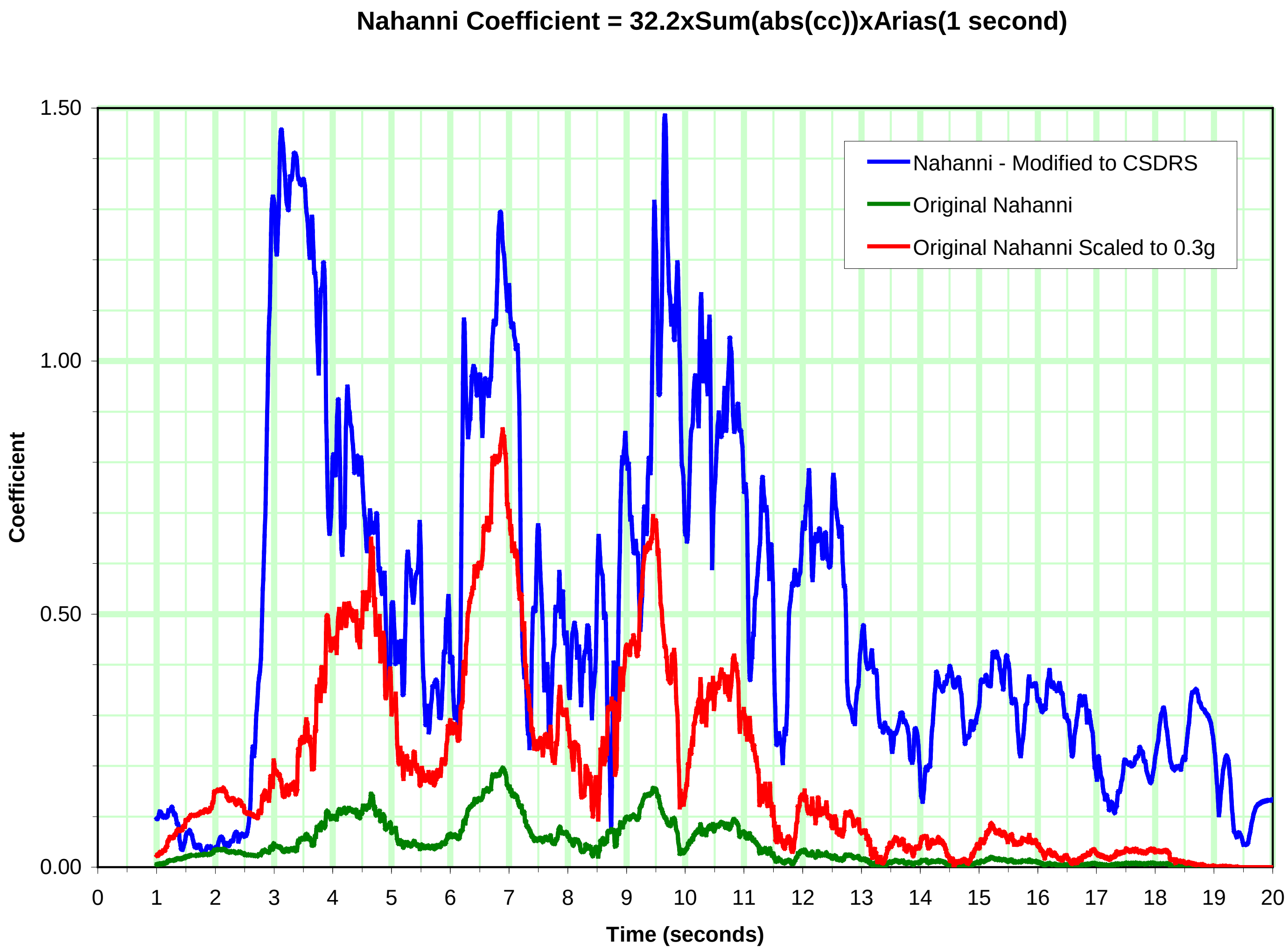
Resolution

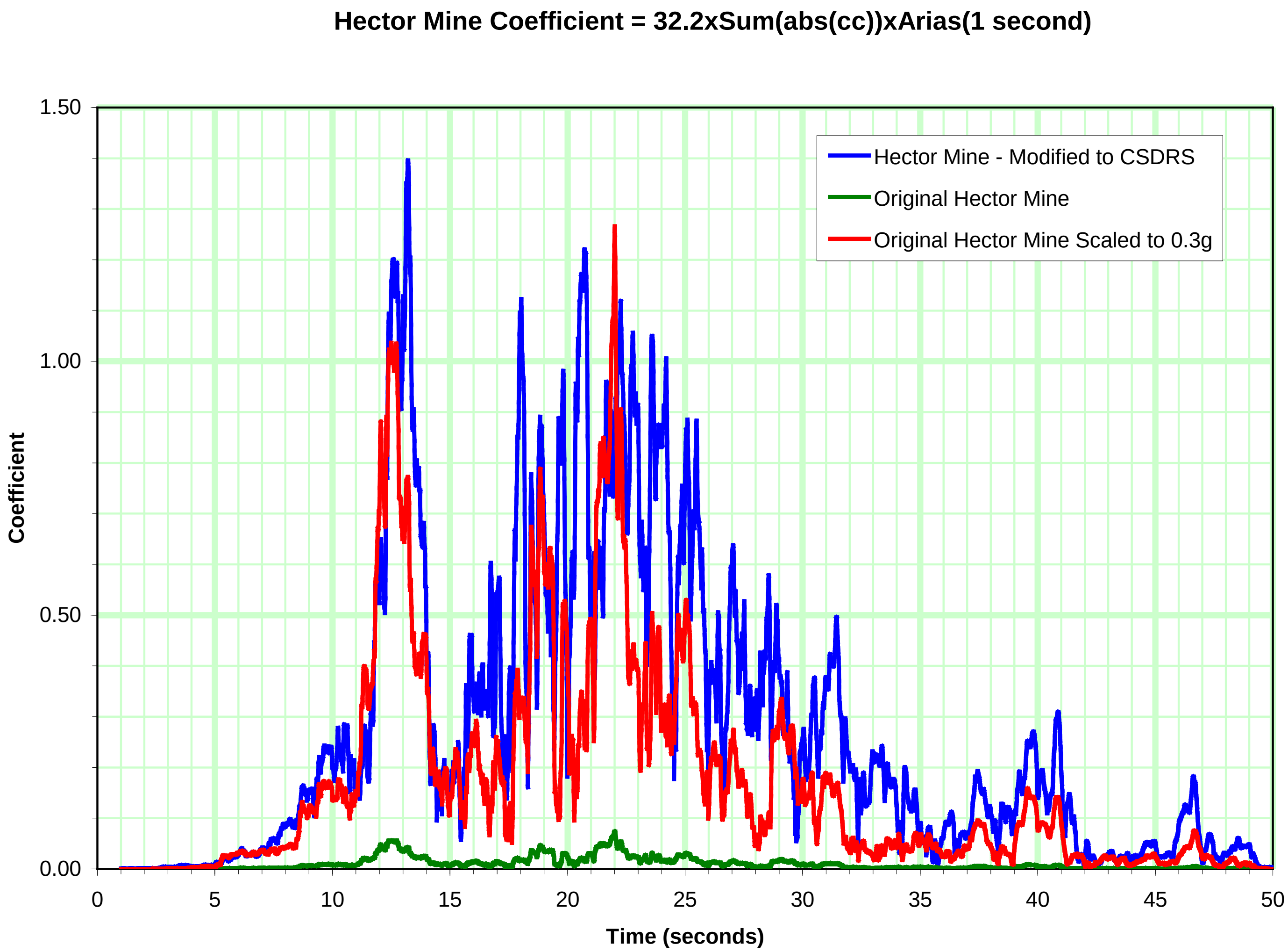
- **All Earthquakes were developed to match the CSDRS per the guidance in NUREG 0800**
- **Using this coefficient the signals from Loma Prieta and Northridge were not used to analyze the R/B Complex**
- **The Hector Mine Desert Hot Spring and the Nahanni signals were used to analyze the R/B Complex**
- **The following two slides show the coefficient for the Nahanni and Hector Mine signal development**

Resolution



Nahanni Coefficient = 32.2xSum(abs(cc))xArias(1 second)
Coefficient
Time (seconds)
0.00
0.50
1.00
1.50
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Nahanni - Modified to CSDRS
Original Nahanni
Original Nahanni Scaled to 0.3g

Resolution



Hector Mine Coefficient = 32.2xSum(abs(cc))xArias(1 second)
1.50
1.00
0.50
0.00
Coefficient
0
5
10
15
20
25
30
35
40
45
50
Time (seconds)
Hector Mine - Modified to CSDRS
Original Hector Mine
Original Hector Mine Scaled to 0.3g

Resolution

- The Reactor Building complex was analyzed using SASSI and the resulting moments and vertical forces extracted for both time histories developed to match the CSDRS
- The following two tables provide data for the relative values of the seismic moments Mx and My and vertical seismic force Fz for the first 50 steps with decreasing moment

Resolution

- The data was developed as follows:
  - ✓ Using the data for each site profile
  - ✓ Normalize the two moments (Mx and My) and the vertical force Fz to their maximum values using the first 50 absolute values
  - ✓ Sort the normalized moment values in descending order starting at 1.00
  - ✓ Compute the SRSS of the normalized values and select the highest value from either the Mx or My ordered values with Fz/Fzmax>0.4
  - ✓ Report the normalized Mx, My and Fz

Resolution

HECTOR MINE seed				
Soil Profile	Fz/Fzmx	Mx/Mxmx	My/Mymx	$\mathrm{Sqrt}[(Mx/Mxmx)^2+(My/Mymx)^2]$
270-200	0.585	0.650	0.890	1.102
270-200RV	0.484	0.694	0.886	1.126
270-500	0.428	0.628	0.935	1.126
270-500RV	0.419	0.624	0.948	1.135
560-500	0.621	0.733	0.834	1.111
560-500RV	0.618	0.779	0.807	1.122
900-100	0.445	0.123	1.000	1.007
900-100RV	0.430	0.748	0.737	1.050
900-200	0.418	0.176	1.000	1.015
900-200RV	0.401	0.739	0.767	1.065
2032-100	0.438	0.238	0.999	1.027
2032-100RV	0.427	0.716	0.785	1.063

Resolution

NAHANNI seed				
Soil Profile	Fz/Fzmax	Mx/Mxmx	My/Mymx	Sqrt[(Mx/Mxmx)^2+My/Mymx)^2]
270-200	0.435	0.725	0.866	1.129
270-200RV	0.443	0.723	0.871	1.132
270-500	0.456	0.689	0.866	1.106
270-500RV	0.403	0.844	0.756	1.133
560-500	0.581	0.524	1.000	1.129
560-500RV	0.526	0.524	1.000	1.129
900-100	0.411	0.641	0.884	1.092
900-100RV	0.434	0.130	1.000	1.008
900-200	0.427	0.655	0.887	1.103
900-200RV	0.442	0.107	1.000	1.006
2032-100	0.435	0.667	0.926	1.141
2032-100RV	0.409	0.675	0.914	1.137

Resolution

- **Generally either of the two signals could have been used to analyze the structures for the US-APWR, though the Nahanni signal produces the more aggressive responses for most of the soil profiles**
- **SRSS (1,0.4) = 1.077**
- **The Hector Mine seeded time history does not provide this value for the 900 or 2032 soil profiles**
- **Thus, considering that the Nahanni signal is representative of a CEUS seismic event, it was selected for analysis**

Summary

- The revised time histories provide a better fit to the CSDRS
- The revised time histories resolve challenges associated with contact area ratio and bearing pressure
- The revised time histories help in resolving stability challenges
- The revised time histories do not result in a reduction of critical peaks in the design basis ISRS

Summary

- **MHI has documented methodology and results for revised time histories in the October revision of Technical Reports**
- **DCD will be updated to include the revised time histories in MUAP-10001 Rev. 4**

US-APWR

Concluding Remarks

Overview of US-APWR Seismic Technical Reports

November 7, 2011

Mitsubishi Heavy Industries, Ltd

Concluding Remarks

➢ Conclusion

- ✓ Provided a review of the revision contents of Seismic Technical Reports submitted in October 2011
  - Discussed status of TR MUAP-11001 and MUAP-11011
  - Discussed plan for RAI responses associated with TR submittals
- ✓ Discussed changes to the design basis input

Concluding Remarks

➢ Path Forward

- ✓ Licensing documentation related to October TR submittals
  - Submit historical RAI responses by November 2011
  - Submit DCD mark-up reflecting TR updates by November 2011
  - Submit response to recent RAIs in accordance with plan
- ✓ MUAP-11001 and MUAP-11011
  - Execute plan for submittal by January 2012 (to be finalized)
  - Update RAI responses and DCD mark-up as necessary
- ✓ Continue interactions with NRC Staff to identify progress updates (i.e. future public meetings)